# SUBSCRIBER CARRIER EQUIPMENT

CONTENTS



## 1. GENERAL

1.01 This section is intended to provide REA borrowers, consulting engineers and other interested parties with technical information on subscriber carrier equipment and its varied applications. This equipment has now been developed to the degree where it should be considered in the system designs of REA borrowers. Additional information pertaining to carrier system fundamentals as applied to subscriber carrier equipment can be found in Section 901, Issue No. 2 of the REA-Telephone Engineering and Construction Manual.

1.02 Subscriber carrier channels can be superimposed upon existing or proposed physical subscriber circuits which meet transmission requirements with a minimum of investment in order to derive additional subscriber circuits on the same wire pair without degrading the basic physical circuit. Each channel provides all of the apparatus necessary for a two-way talking circuit with dialing from and full selective ringing to carrier derived subscribers without any modifications to the central office equipment or telephone sets normally used by the telephone company.

2. CONDITIONS UNDER WHICH APPLICATIONS WILL BE APPROVED

2.01 The applications of various forms of subscriber carrier equipment should be considered in all system designs of REA borrowers in situations where significant savings in both initial and annual costs can be realized by their usage. The more apparent application situations wherein significant savings might be made are described in Paragraph 4.

2.02 Properly engineered applications of subscriber carrier equipment which effect substantial net economies as compared with conventional means of providing subscriber circuits will be approved without regard to a fixed percentage of subscribers to be served as was previously required when such carrier systems were in a comparatively new stage of development. Since substantial economies can only be realized by the proper layout of such carrier systems, and since little information is as yet available pertaining to the most economic layouts, it is recommended that in complex application situations which provide telephone service to over 10 percent of the 5-year subscribers by means of subscriber carrier equipment the Consulting Engineer submit application information to the Section Engineers for comment in advance of the Area Coverage Design. In this manner possible changes in the ACD may be suggested in order to realize greater economies while avoiding resulting loss of time and additional expense as a result of possible changes in the manner of providing carrier circuits. This procedure will be followed until more application information becomes available for various types of subscriber carrier equipment.

2.03 The advance submission of application information for more complex situations should be similar to that which the engineer will prepare in order to purchase carrier equipment by use of REA Form 813 - "Technical Considerations Affecting the Application of Trunk and Subscriber Carrier Equipment." REA-TE & CM-Section 902 is an application guide for the proper completion of this form while REA Bulletin 344-4 explains the procedure governing its use.

\th the advance submission of application infor-
-ibed above the engineer should also submit an
;ification of the proposed application.

iarges as given in the REA-TE & CM-Section 218
:d for cost comparison studies for subscriber
ment until additional information becomes
ilthough experimental installations of such

equipment made by various manufacturers have proved encouraging thus far the limited amount of information available concerning annual charges make the annual cost economies somewhat questionable and may therefore limit to a certain extent the number of carrier applications in REA borrowers' systems at this time.

## 3. MAJOR OPERATING CHARACTERISTICS

3.01 REA has now conducted field trials and laboratory studies on subscriber carrier systems of various types and manufacture or has been supplied complete circuit diagrams and transmission data regarding such systems. The engineer can obtain details concerning these various types of carrier systems from the manufacturers together with delivery dates, current selling prices for terminals and accessories, and installation and lineup costs. The cost per channel for this type of equipment will vary for each installation, depending upon the number and type of terminals, filters, cabinets, spare parts, and other accessories which are required. The central office carrier terminals referred to herein are defined as the terminals connected to the central office equipment by means of a voice frequency pair, while the subscriber (remote) terminals are defined as the terminals to which carrier derived subscribers are connected by means of a voice frequency pair.

3.02 Number of Channels Available - The maximum number of stackable channels available from any one manufacturer for use on a wire pair is 10. Most manufacturers have less than 10 stackable channels available at present. The physical circuit upon which these carrier channels are superimposed is also usable, therefore a maximum of 11 subscriber circuits could be provided on one wire pair using the equipment of a single manufacturer. By the proper selection of operating frequencies and filters, subscriber carrier channels of two manufacturers can be superimposed on a single wire pair to provide an even greater number of circuits.

3.021 In some application situations where carrier channels of two manufacturers are to be used to provide a maximum number of carrier derived circuits on one wire pair certain channels on some routes may be subject to harmful interfering effects from power line carrier systems or other possible sources of interference at carrier frequencies. To prevent the possibility of having insufficient channels available is such a condition were to occur the engineer should not plan to

utilize the maximum possible number of channels on one wire pair unless accurate measurements of carrier frequency power have shown that no interfering frequencies are present. With this arrangement for utilizing carrier channels it will then be possible to substitute one or more carrier channels whose frequencies are not subject to interference in a particular area for those channels which are subject to harmful interference. The measurements of interfering carrier frequency power should preferably be made at various times of the day or over a period of several days if practicable so that it will be possible to measure sources of interference which may only be present during certain intervals.

3.022 Similar situations of harmful interference may develop with certain channels of only one manufacturer. In these situations other channels of the same manufacturer can usually be substituted for the channels subject to interference or carrier channels of a second manufacturer can usually be provided in order to derive the required number of circuits.

3.03 Frequency Range - The carrier and sideband frequency ranges at which subscriber carrier channels function presently extend from approximately 3.5 kc to 345 kc. The actual operating frequencies for any particular type of equipment can be obtained from the manufacturer. In general, presently available five channel subscriber carrier systems occupy frequency ranges extending from approximately 3.5 kc to 62 kc, from 7 kc to 103 kc, and from 24 kc to 138 kc, while 10 channel systems occupy frequency ranges extending from approximately 47 kc to 338 kc or from 54 kc to 345 kc.

3.04 Number of Frequency Allocations - Some types of subscriber carrier equipment are available with only one frequency allocation while other types provide in effect two separate frequency allocations by utilizing frequency staggering, sideband inversion or both of these techniques. Two frequency allocations for the same type of carrier equipment permit the use of stackable carrier systems on more than one wire pair along the same route. This is for application situations where the crosstalk loss at carrier frequencies between wire pairs would not be great enough to permit the proper operation of more than one stackable carrier system utilizing the same frequency allocation.

3.05 Maximum Carrier Frequency Line Losses Between Terminals, Between Terminals and Carrier Repeaters, or Between Repeaters - 25 to 36 db, depending upon the particular type of carrier equipment and manufacturer's recommendations. Under certain

conditions carrier channels of some manufacturers may function satisfactorily on wire pairs whose attenuation exceeds the values listed above but it is felt that in system designs the maximum loss should be limited to the above values to assure a good carrier signal-to-noise ratio during adverse weather conditions, during periods of high summer static, or where carrier channels are exposed to interfering effects at carrier frequencies from adjacent power lines, power line carrier systems, or other potential sources of interference.

3.06 Types of Ringing Power Output - Four basic ringing power outputs as described below are now available for subscriber carrier channels. Changing from one type of ringing power output to another, except for the condition given in 3.062 below, usually requires changes in the type of signaling terminations at both the central office and subscriber terminals of the carrier channels and cannot be accomplished by simple terminal strapping changes. Furthermore, all subscriber carrier manufacturers do not provide each of the types of ringing output mentioned herein. The ringing outputs designed to supply sufficient power for each type of arrangement, are summarized below:

3.061 Ten party full selective ringing when used with the proper type of high impedance telephone ringers such as those provided in the "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers" where the central office ringing power output at any one of five separate frequencies is applied between either the tip or ring side of the line and ground at the central office carrier terminal.

3.062 Five party full selective or ten party semi-selective ringing when used with the proper type of high impedance telephone ringers where central office ringing power output at any one of five separate frequencies is applied between either the tip or ring side of the line and ground at the central office carrier terminal. In this type of equipment the subscriber terminal only applies ringing power between the tip and ring sides of the line even if this power is applied between either side of the line and ground at the central office terminal. In situations where for line noise or other reasons it is more desirable to connect all ringers beyond a subscriber terminal in a bridged arrangement (between tip and ring sides

of the line only) the full selective ringing type of carrier equipment described in 3.061 above can usually be strapped for providing either five-party full selective or ten party semi-selective ringing. In semi-selective ringing applications the central office equipment must be capable of supplying at least two ringing codes to the carrier equipment to enable a subscriber to distinguish his ring. These codes are normally provided in central office equipment purchased under the REA Central Office Equipment Specifications (REA Form 558a, b, or c).

3.063 Four party full selective or eight party semi-selective superimposed ringing when used with the proper type of biased polarized ringers (usually 20 c.p.s.) and cold cathode tubes where the central office ringing power output supplied to the central office carrier terminal consists of a.c. ringing power superimposed on either a positive or negative d.c. voltage. In this type of equipment the subscriber terminal reproduces the ringing power and superimposes it on a positive or negative d.c. voltage (which it also produces) for application between either the tip or ring side of the line and ground.

3.064 One party bridged ringing in situations where subscriber carrier channels are used for individual line service. In this type of equipment the subscriber terminal applies the bridged ringing power (usually a locally generated 60 cps frequency) to the single subscriber's telephone set when the proper ringing voltage is applied either in a bridged or divided arrangement to the central office carrier terminal. The number assignment for the individual line subscriber can be made in the usual manner as outlined in Paragraph 3.03 of Section 216 of the TE & CM since the subscriber terminal will reproduce 60 cps ringing output for any ringing frequency applied to the central office terminal.

3.07 Type of Central offices with which Carrier is to Function Properly - Either dial or common battery manual.

3.08 Maximum Permissible DC Loop Resistance of Voice Frequency Drop Connected to Subscriber Terminal - 390 to 1500 ohms, depending upon the particular type of carrier equipment utilized. These values may or may not include the resistance of the telephone set, depending upon the manufacturer of the carrier equipment.

3.09 Filters Available - Various manufacturers of subscriber carrier equipment have complete lines of voice pass (low pass filters for bridged station applications described more fully in Paragraph 5.02), carrier pass (high pass filters for sectionalizing a wire pair (Paragraph 5.06) so as to permit voice frequency operation in two sections of the same wire pair while providing a minimum loss to through carrier frequencies) and line filters for either indoor or outdoor mounting with or without built-in electrical protection apparatus. Details on the application of these filters in various carrier layouts are given in subsequent paragraphs.

3.10 Outdoor Cabinets Available - Weatherproof outdoor cabinets are available from carrier manufacturers for housing from one to five subscriber terminals or central office terminals (in situations where the central office terminals have to be mounted at locations external to the central office) in various types of pole mounting arrangements. These cabinets usually contain convenience outlets (117 V AC power) for test equipment while some types are available with one or more features such as built-in electrical protection for voice and carrier frequency pairs, mounting arrangements for a voltage regulator if required, thermostically controlled blowers for cooling the carrier terminals, and provisions for attaching sun shields.

3.11 Rack Space - Each central office terminal usually occupies from $5\frac{1}{4}$ to 7 inches of vertical height on a 19 inch relay rack. The depth of these terminals varies considerably depending upon the particular type of carrier equipment. In addition, other central office mounting arrangements provide for the use of a separate panel for line filters, transformers, etc., or for mounting two terminals side by side on a 19 inch rack.

3.12 Power Supplies - Some types of central office terminals can be normally powered directly from the nominal 48 volt central office battery supply while other types can be normally powered only from 117 volt a.c. sources. Where these terminals are powered directly from the central office batteries it is important that the total current drain be considered in the battery and charger capacity of the office so as not to deplete the busy hour reserve of the batteries. At present all vacuum tube type subscriber terminals are designed to be

normally powered only from 117 volt a.c. sources. Transistorized subscriber terminals are capable of being powered either from commercial a.c. sources or from various types of battery power. Subscriber carrier repeaters can sometimes be powered by the central office batteries from an adjacent office by means of cable pairs linking the repeater with the central office or by means of various types of battery supplies mounted at the repeater location.

3.13 Standby Power-Can be provided by carrier manufacturers for commercially powered central office terminals or for subscriber terminals in situations where this feature can be economically justified if the commercial power supply is subject to frequent outages. Usually vibrator or rotary type converters are used to supply a.c. power from storage battery sources for standby purposes.

3.14 Power Consumption - Each central office or subscriber terminal which utilizes vacuum tubes has a power consumption ranging from approximately 25 watts to 50 watts during idle circuit conditions, depending upon the particular type of equipment. With completely transistorized carrier equipment the power consumption for each channel terminal during the idle condition will probably not exceed several watts. In situations where vacuum tube type central office terminals are pole mounted at external locations, such as at cable-open wire junctions, or where either vacuum tube or transistorized subscriber terminals are powered from commercial alternating current sources the power consumption will probably not be of a sufficient quantity to exceed the cost of the minimum electric bill for each external location unless a number of channel terminals can be mounted at these locations. This latter arrangement is advantageous in reducing the total cost of power consumed by this equipment and has further advantages as discussed in Paragraph 4.052.

3.15 Revertive Calling - Subscriber carrier systems described herein will function satisfactorily without carrier equipment modifications when used with revertive calling arrangements such as provided by central offices purchased in accordance with the REA Central Office Equipment Specifications.

3.16 Paystation Operation - Subscriber carrier systems described herein are not suitable without circuit modification for connecting paystations (types normally utilized by REA borrowers)

with central offices. Where paystation use is contemplated the physical circuit upon which the carrier channels are superimposed may be suitable for this application or the carrier manufacturers should be supplied with detailed circuit diagrams of the paystation and central office circuits associated with the paystation so that they can determine if the carrier equipment can be modified so as to function properly.

4. APPLICATION SITUATIONS

4.01 The characteristics of subscriber carrier equipment which permit the concentration of more than one subscriber circuit upon the same wire pair and its flexibility in being installed and removed from service at low cost provide a very useful technique for designing rural telephone systems. Some of the more apparent application situations wherein the use of subscriber carrier equipment might result in significant savings are summarized in the following paragraphs.

4.02 An example of the use of subscriber carrier equipment in system design is shown in Figure 1. The Cuprous Subscriber Data indicates there will probably be a total of 29 subscribers within 10 years. Backbone plant would have to be provided for serving this number of subscribers. With conventional system design techniques and based on a maximum line fill of 10 parties per line a minimum of 3 wire pairs would eventually have to be built between the Purdue central office and Cuprous. If, as might happen in a village such as Cuprous, one or more business telephones or 2- or 4- party service is desired additional wire pairs would have to be provided for this route. Even though only 4 signed subscribers in Cuprous desire to receive telephone service initially it would be good engineering practice to provide backbone plant consisting of poles of the proper class and height and crossarms of the proper type so that a five circuit route is made available to allow for future growth. A 10 pin crossarm lead with a minimum of 6 wires attached might preclude economical use of existing poles of electric supply organizations in joint use arrangements due to the consideration of pole strength margins.

4.021 Figure 1 also shows a rural line extending 7 miles beyond Purdue before it connects with a total of 13 signed or potential subscribers located along this route. Even though only 2 signed subscribers may

desire service initially conventional techniques would make it necessary to construct the proper backbone plant for providing at least 2 wire pairs over the major portion of this route.

4.022 By utilizing stackable subscriber carrier channels in the system design for both of the above situations either initially or to provide for growth on a planned basis should it materialize it is entirely feasible to construct backbone plant with an absolute minimum of fixed plant consisting of only one wire pair per route and still have a system design with the flexibility necessary for meeting either predicted or unforseen conditions of growth. This carrier plan permits a minimum of investment now in order to care for future growth. If growth does not materialize no investment need be made in carrier equipment. Conversely, if growth exceeds expectations or if unexpected service regrades are requested stackable carrier channels can be added to meet the requirements. This plan also permits more consideration of joint use possibilities since pole strength requirements are eased when only one wire pair per route is required.

4.023 Planning for the use of subscriber carrier equipment initially insures that adequate carrier transmission requirements, proper transposition systems, etc., will be attained. This approach eases system design requirements for carrier equipment since the plant facilities can be planned initially with maximum carrier usage in mind.

.03 Another readily apparent application situation is where groups of rural subscribers, such as those living at crossroads communities, etc., are located too far from an existing or planned central office to economically meet signaling and transmission requirements and, under conventional practices, a community dial office equipped with a small number of lines would have to be provided at this location. An example of such a situation is shown in Figure 2 for the community of Hayes Crossroads. In this situation, 7 circuits will be required in 5 years while a total of 13 circuits will be required in 10 years in order to meet the demand for both graded and party line service. A conventional approach to providing service in this area would be to install a community dial office at Hayes Crossroads together with trunk carrier

and/or voice derived trunks to link this central office with the toll center and probably with Hillsboro for extended area service trunks. Another possible conventional approach for serving subscribers in this area would be by use of loaded cable pairs from the Hillsboro central office. The relative cost of coarser gauge pairs, however, would probably preclude the use of loaded cable over the 15 mile path. Voice frequency repeatered subscriber lines are another possibility, but repeater costs together with loaded cable facilities would probably be in excess of subscriber carrier costs. Multi-channel subscriber radio circuits might be practicable for this route depending upon terrain considerations and the relative costs of wire line construction in this area.

4.031 Hayes Crossroads could probably be economically-served by means of stackable subscriber carrier equipment by either of the following plans:

Plan 1 - Initially build one physical open wire circuit, suitable for carrier transmission, and superimpose six channels of subscriber carrier on it. This would provide the necessary circuits for meeting the 5 year requirement. The additional channels necessary for meeting the 10 year requirement can be added to this wire pair in the future when the need arises. With use of only one wire pair as described herein the present state of the art would require that subscriber carrier equipment of two manufacturers be utilized in order to derive the required number of circuits. (Paragraph 3.02)

Plan 2 - Initially build two physical circuits properly transposed with three channels of subscriber carrier superimposed on one wire pair and two superimposed on the other pair or, if filter requirements are such that the expense would be substantially larger by superimposing carrier channels on two wire pairs, superimpose all five channels on one of the two wire pairs. This would provide the necessary circuits for meeting the 5 year requirement. The additional channels necessary for meeting the 10 year requirement could be added to one or both of these wire pairs in the future when the need arises. With the use of two wire pairs as described herein subscriber carrier equipment of only one manufacturer can be utilized in order to derive the required number of circuits.

4.032 By utilizing subscriber carrier equipment for serving Hayes Crossroads a community dial office, land, buildings and trunk circuit equipment can be eliminated. Since only one or two wire pairs neer be provided even for future growth there will also be savings in outside plant items such as wire, crossarms, protectors, drainage units and various hardware items and the subscriber route might be such that smaller poles can then be used. Furthermore, with the use of only two wire pairs it may be possible to economically utilize the existing poles of electric supply organizations in joint use arrangements since strength margins for these poles may not be exceeded. Other advantages of such an arrangement would be a simplified numbering scheme as compared with the situation that would exist if EAS circuits were to connect a CDO with Hillsboro together with a separate trunk group for connecting with the toll center.

4.033 With the utilization of subscriber carrier equipment as described above savings can be made in both initial and annual costs for backbone facilities since, as described previously, a minimum of such facilities need be provided. The investment in facilities for growth, which earn no immediate return, need not be made. If the expected growth in Hayes Crossroads does not materialize no financial loss is incurred in the provision of backbone facilities which will be unused and cannot be salvaged economically since no additional carrier channels need be ordered. If, on the other hand, the expected growth in this community exceeds predictions or if some subscribers request service regrades Plan 2 would make it entirely feasible to add even more carrier channels for deriving additional subscriber circuits. If the growth in this community at some future date became so great that it would no longer be economical to serve it by means of various types of stackable subscriber carrier equipment then available a community dial office could be constructed. The same wire pair (or pairs) upon which the subscriber carrier channels were superimposed could then be used for trunk carrier channels between Hayes Crossroads and the toll center and for EAS circuits, if desired, between Hayes Crossroads and Hillsboro. A number of the existing subscriber carrier channels could then be converted to trunk carrier channels by simply changing the signaling terminations while the remainder of these channels could be installed at other locations or otherwise salvaged. If such a CDO were installed in the future the advantages of the simplified numbering scheme previously mentioned would no longer be applicable.

4.04 In Figure 3b an application situation is illustrated whereby subscriber carrier channels are superimposed upon an existing 10 party line (Figure 3a) without extensive modifications so that additional 2-party graded service and individual line service can be provided, assuming the wire pair meets carrier transmission requirements. By the proper placement of voice pass filters (Paragraph 5.02) and line filters (REA-TE & CM-901) the existing line is treated so that the carrier terminals can be mounted at the locations shown. There should be no mutual interference between the physical circuit and the carrier circuits with such an arrangement. This type of application can be utilized where service regrades are requested along a route already filled to capacity and in situations where growth in rural areas requires that individual lines be provided for new homes, business establishments, etc. Such applications will become more important as rural areas grow and subscribers demand better grades of service.

4.041 Under conventional practices separate wire pairs would have to be constructed from the central office to the locations where these additional telephones are to be installed. In many situations the cost of providing these separate wire pairs would not be economical as pole changeouts, additional crossarms, etc., would be required.

4.042 Although this example illustrates the use of only 2 carrier channels it is possible to utilize many more stackable channels over the same facilities under similar conditions so as to further save on outside plant facilities while providing for telephone system growth.

4.05 Figures 4 and 5 illustrate the application of subscriber carrier channels for party line service. Figure 4a illustrates a typical conventional 5 pair open wire route utilized to serve 40 subscribers (assuming a party line fill of 8 subscribers) while Figure 4b illustrates one type of subscriber carrier layout where 4 carrier channels are utilized for serving 32 of the 40 subscribers. There is a significant difference in the number of miles of wire pairs needed in both layouts. In addition to the saving in wire pairs the subscriber carrier layout would also result in savings in the cost of hardware items, protectors, poles, etc., as explained previously. This subscriber carrier layout could be utilized where party line subscribers are located at some distance from the main pole line route and

in situations where a voice frequency pair from the subscriber terminal could be economically constructed to parallel the carrier wire pair on the same pole line route. The number of voice pass filters required for this type of layout is primarily dependent upon the number of subscribers served on the basic physical circuit. Although the illustration shows 8 subscriber stations on the physical circuit having voice pass filters connected between them and the carrier line many situations will arise where more than one physical subscriber can be served from a single voice pass filter as shown in Figure 3b and discussed in more detail in Paragraph 5.02.

4.051 Figure 5a illustrates another method of utilizing 4 subscriber carrier channels for serving 32 party line subscribers. In this illustration much greater use is made of voice pass filters and line filters together with carrier pass filters for blocking direct, ringing and voice currents (Paragraph 5.06) in order to serve the entire 40 subscribers by means of a single wire pair. This latter type of filter sectionalizes the line at voice and ringing frequencies so that it can be used for serving separate groups of subscribers connected on each side of the filter. The use of more voice pass filters has resulted in a further savings in wire pair miles as compared with Figure 4b. Although more voice pass filters are now used many application situations will undoubtedly arise whereby the additional cost of purchase and installation of these filters will still probably be less than that of the installed cost of additional voice frequency wire pairs for connecting the voice frequency drops of the subscriber terminals with the subscriber stations. Confining the entire party line layout to one wire pair would again make it possible to utilize joint-use construction to a fuller degree even in heavy loading areas.

4.052 Figure 5b illustrates a desirable method of utilizing 4 subscriber carrier channels for serving 32 party line subscribers. In this layout the subscriber terminals are so arranged that they serve subscribers from only two separate locations as compared with the 4 separate locations shown in Figures 4b and 5a. This type of layout is accomplished by utilizing only one line filter to permit transmission of carrier currents

in the proper direction together with carrier pass filters. Another method of line treatment sometimes used for the subscriber terminal locations as shown in Figures 5a and 5b is by means of bandpass filters to confine carrier currents to the proper direction of transmission while simultaneously providing the sectionalizing features of carrier pass filters. In addition to reducing the number of line filters some important advantages of having fewer subscriber terminal locations are summarized below:

1. The number of carrier terminal locations is decreased thereby minimizing the number of locations where maintenance is performed.

2. Savings in commercial power bills can be realized since metered power is required at fewer locations.

3. Savings in the number of pole mounted equipment cabinets can be realized.

4. If commercial power voltage regulation is such that voltage regulators must be provided to insure long vacuum tube life the installed cost of a larger capacity voltage regulator may be substantially less than the cost of several smaller voltage regulators mounted at separate locations.

5. If the commercial power supply at pole mounted terminal locations is subject to frequent outages and standby power facilities must be provided the cost of standby power on a per channel basis should be substantially decreased.

4.06 Figure 6 illustrates an application where subscriber carrier equipment can be economically utilized on long subscriber circuits in situations where conventional facilities such as long line adapters or extremely high cost wire plant would be required for reaching remotely-located subscribers or groups of subscribers. The basic physical circuit between the central office and physical subscriber P is such that the central office would probably have to be equipped with a long line adapter for this circuit. Subscribers well beyond this location, such as S, can be provided with telephone service by means of subscriber carrier equipment superimposed

on the same 28 mile physical circuit without the use of long line adapters since subscriber carrier systems are capable of serving additional subscribers on another 390 - 1500 ohm loop beyond the subscriber terminal (Par. 3.08). This subscriber loop beyond the carrier terminal can consist of copper clad or galvanized steel wire, rural distribution wire, etc., depending upon the distance between subscriber terminal S1 and S. With conventional wire plant it may not be possible to serve the extremely remote subscribers such as S even with long line adapters unless high cost wire plant were constructed for the entire route. With subscriber carrier the conductors shown in Figure 6 can be utilized since carrier transmission requirements are met for most subscriber carrier equipment. Flexibility in circuit requirements can also be maintained over such a route since other subscriber carrier channels can be added at various locations in a manner similar to that illustrated in Figure 3.

4.07 Figure 7 illustrates an application whereby a portion of an existing or proposed trunk carrier route linking the Simpson and Baker CDO's can also be utilized for subscriber carrier applications by proper selection of carrier channels and filters. In this example the physical circuit plus two trunk carrier channels are utilized for EAS trunks between these offices while 3 subscriber carrier channels from the Simpson CDO utilize a portion of this same wire pair to connect with rural subscribers. With this type of application there is no physical subscriber loop available since the physical circuit is used for trunk purposes. Depending upon circuit requirements, transmission limitations, etc., it would also be possible in some situations to simultaneously utilize subscriber carrier in a similar manner from the Baker CDO in order to derive further use of the wire pair linking Simpson and Baker. Applications of this type will be particularly advantageous in situations where appreciable savings can be made in outside plant facilities since only a minimum amount of additional plant need be constructed between the trunk wire pair and the subscriber terminals of the carrier equipment, and in situations where physical limitations such as pole strength, clearances, etc., make it impossible to provide more wire pairs along an existing route.

.08 An important application in which subscriber carrier channels might be utilized economically is in situations where the number of conventional telephone circuits needed along particular routes exceed the number of such circuits permitted

on existing electric supply system poles with which joint-use would be economical. Joint-use was mentioned briefly in previous paragraphs describing other possible applications. Stackable subscriber carrier channels can be used in certain applications to sufficiently reduce the number of physical telephone pairs required on a joint-use basis so as to meet pole strength margins and thereby make such an operation practicable.

4.09 Another possible application of subscriber carrier is in situations where the use of such equipment can sufficiently reduce the number of physical wire pairs per route so as to eliminate or reduce the amount of cable plant required in the telephone system, with the exception of short lengths of entrance cable.

5. TRANSMISSION CONSIDERATIONS

5.01 Paragraph 15 of the REA-TE & CM-Section 901, Issue No. 2, describes some of the more important transmission aspects which must be considered for a properly engineered carrier system. In addition to selecting a particular type of carrier equipment it is extremely important that proper considerations be given to the voice and carrier frequency transmission of the wire facilities upon which the carrier systems are superimposed.

5.02 Figure 8 is an illustration of a common type of subscriber layout whereby three channels of subscriber carrier equipment are superimposed upon a physical circuit which also serves eight party-line subscribers. This illustration will first be used to explain the application of voice pass filters.

5.021 Voice pass filters are a type of low pass filter designed to pass direct currents, ringing currents and voice frequency currents with a minimum transmission loss while providing a high transmission loss to any carrier frequency currents. Other terms such as bridged station, waystation, isolation or blocking filters are sometimes used by various carrier manufacturers for describing these filters. Voice pass filters must be installed at all subscriber taps in situations where portions of the subscriber loop are also used simultaneously for carrier transmission.

In addition, either a voice pass or other type of low pass or line filter must be installed at the central office terminals as shown so as to provide the proper directions of transmission for voice and carrier frequency currents. The type of filter utilized at this location will vary, depending upon the type of carrier equipment which is provided. In this illustration one voice pass filter is shown at the central office terminals while three of these filters are shown at intermediate locations along the wire pair linking the carrier terminals.

5.022 Voice pass filters must be used in a layout such as illustrated in Figure 8 for the following reasons:

1. To prevent short circuiting of the carrier currents by the telephone set whenever a subscriber on the physical circuit is dialing.

2. To prevent additional carrier frequency transmission losses when the telephone set or other apparatus on the physical circuit shunts the carrier frequency line.

3. To prevent harmful interfering effects to voice frequency transmission on the physical circuit as a result of demodulation of carrier frequency currents by varistors or other non-linear circuit elements utilized in modern telephone sets.

4. To prevent additional carrier frequency transmission losses due to reflection effects when voice frequency taps are connected to the wire pair utilized for both voice and carrier frequency transmission.

5. To prevent harmful modulating (interference) effects to carrier frequency currents as a result of voice frequency transmission on the physical circuit.

5.023 It can be seen from Figure 8 that only one voice pass filter is inserted between a voice frequency tap and the wire pair utilized for both voice and carrier frequency transmission in situations where one or more

voice frequency subscribers are served from the tap. By physically locating these filters at the junction between the main route and each voice frequency tap as shown only a minimum number of filters have to be provided while any reflection effects at carrier frequencies due to taps are thereby eliminated. This latter consideration is particularly important where higher carrier frequencies are being utilized because if the filters are mounted at subscribers' residences the distance from the tap to these residences may approach a quarter wavelength and serious transmission impairment would then occur at certain carrier frequencies.

5.024 Since subscriber carrier equipment is now available which operates over different frequency ranges various types of voice pass filters have been developed to perform satisfactorily with each of these systems. As a result some voice pass filters (those designed for operation with relatively low frequency carrier systems) provide high insertion losses at frequencies just above the voice frequency range while others (those designed for operation with relatively high frequency carrier systems) only begin to provide high insertion losses at frequencies somewhat below the lowest operating frequency of the relatively higher frequency carrier systems. It is necessary therefore in initial or future situations where more than one manufacturer's subscriber carrier equipment is superimposed on the same wire pair (Paragraph 3.02) that voice pass filters which are to be installed initially should be of a type which will function satisfactorily over the entire carrier frequency range which will be used in the future. For example, if higher frequency carrier channels of one manufacturer are to be installed initially and lower frequency carrier channels of another manufacturer are planned for the future on the same wire pair voice pass filters initially installed should be of a type that have sufficient insertion losses at the lower carrier frequencies to be used in the future. Similarly, the insertion losses of these filters should not decrease substantially at the higher carrier frequencies as a result of the effects of distributed capacitance, etc.

5.03 Protector units such as the Western Electric Company's 108A (also called "Tuned Drainage Units") or the equivalent are frequently utilized on open wire lines to reduce the magnitude of electrically induced voltages to ground in situations where the telephone pairs are in proximity to electric supply lines (REA-TE & CM-Section 820). These units have little or no detrimental transmission effects to voice or low frequency carrier transmission (up to 50 kc) in situations where they are connected to open wire pairs between carrier terminals. At frequencies above 50 kc, however, these protector units begin to have a shunting effect on carrier currents and the resulting transmission losses become significant. These units can be properly treated for use on wire pairs transmitting high frequency carrier currents by adding Western Electric Company's 296D Retardation Coils or equivalent in series with their tip and ring leads or by connecting a voice pass filter (suitable for operation with high frequency carrier channels) in series with their tip and ring leads.

5.04 The manner in which a typical subscriber carrier layout such as shown in Figure 8 is checked to determine if it will meet both voice and carrier frequency transmission is given below:

5.041 At 70 kc, the highest carrier frequency utilized in this example, the 12 inch spaced 080 CW 30 open wire pair has a wet weather attenuation of 0.46 db/mi., while the 22 gauge non-loaded paper insulated cable has an attenuation of 8.5 db/mi. (REA-TE & CM-406, Tables I and II)

Attenuation Calculation at Carrier Frequency (70 kc)

| | | |
|---|---|---|
| 16 miles x 0.46 db/mi. | = | 7.4 db |
| 0.5 mile x 8.5 db/mi. | = | 4.3 db |
| Assumed reflection loss at cable-open wire junction | = | 3 db |
| Total Attenuation at 70 KC | | 14.7 db |

This value is within the manufacturers' recommended maximum value of 25 to 36 db (Paragraph 3.05). The carrier frequency attenuation calculation was made at 70 KC since this is the highest frequency considered in this example and there are no subscriber terminals at more distant locations from the central office. If other subscriber terminals were mounted at more distant locations additional carrier frequency loss calculations

would probably have to be made to make certain that the channels meet carrier transmission requirements even though lower frequency carrier channels would probably be considered for the distant locations. If line filters, repeat coils, etc., must be inserted in the carrier line for any reason an insertion loss at carrier frequencies of 1 db per filter or repeat coil should be added to the calculation given above unless the actual insertion losses of these devices are known. In this example it was assumed there was a reflection loss at the cable-open wire junction of approximately 3 db. It was further assumed that the facilities were impedance matched where the central office carrier terminals connect directly to the cable and where the subscriber terminals connect directly to the open wire pairs. No additional carrier transmission loss is assumed due to shunting effects for the voice pass filters since this loss is negligible at carrier frequencies. If protector units such as the Western Electric Company's 108A are required on the wire pair linking the carrier terminals it is assumed that they will be treated in accordance with the information given in Paragraph 5.03, therefore, no additional carrier transmission loss is assumed. The R1 transposition system has no significant absorption peaks in the frequency range up to 70 KC, therefore, it should be satisfactory from the carrier transmission standpoint for this example (REA-TE & CM-462).

5.042 The net subscriber loop loss for the furthermost subscriber connected by means of a subscriber carrier channel (S1) to the central office is calculated below:

Loop Resistance of .109 Grade 135 Steel Wire Connected Beyond Subscriber Terminal

10.8 miles = 57.02 kf (REA-TE & CM-422, Table V)
57.02 kf x 14.5 ohms/kf = 827 ohms (REA-TE & CM-422, Figure 1).

This value is within the maximum permissible loop resistance beyond the subscriber terminal for most subscriber carrier systems (Paragraph 3.08).

Net Subscriber Loop Loss

| | | | |
|---|---|---|---|
| Loop loss factor for 57.02 kf of .109 Grade 135 Steel Wire (REA-TE & CM-422, Table I) | = | -0.039 | db/kf |
| Uncorrected subscriber loop loss = 57.02 kf x -0.039 db/kf | = | -2.2 | db |
| Relative gain of 5 db Improved Telephone Set to Standard Telephone Set (REA-TE & CM-422, Table II) | = | -4.8 | db |
| Uncorrected subscriber loop loss with 5 db telephone set | = | -7.0 | db |
| Net loss of subscriber carrier system (REA-TE & CM-901, Par. 8.05 and 8.06) | = | /4.0 | db |
| Entrance to central office (REA-TE & CM-422, Table IV) | = | /0.5 | db |
| Net Subscriber Loop Loss | = | -2.5 | db |

The net subscriber loop loss meets the criteria in REA-TE & CM-415, Paragraph 2, since the design of the subscriber's loop together with the subscriber carrier equipment is such that the furthermost carrier derived subscriber has a level of effective transmission which is better than 0 db effective. Since the carrier channel met carrier frequency transmission requirements its voice frequency output controls can be adjusted for a db 4 net loss at 1000 c.p.s. between the voice frequency drops of the carrier channel in both directions of transmission.

5.043 The loop resistance and net subscriber loop loss for the furthermost physical subscriber from the central office for Figure 8 is given below. 8.5 miles of

this subscriber loop is also utilized for the subscriber carrier route.

Loop Resistance

| | | |
|---|---|---|
| 15.84 kf (3 mi.) 109 grade 135 steel wire x 14.5 ohms/kf | = | 230 ohms |
| 42.24 kf (8 mi.) 080 CW 30 wire x 11 ohms/kf | = | 465 ohms |
| 2.64 kf (0.5 mi.) 22 gauge cable x 32.4 ohms/kf | = | 85 ohms |
| 60.72 kf Total Loop resistance conductors | = | 780 ohms |
| Total Resistance (d.c.) of two voice pass filters in subscriber loop | = | 140 ohms |
| (Assumed resistance of 70 ohms/filter with one filter connected at C.O. end of loop) | | |
| Total Loop Resistance | = | 920 ohms |

The value of loop resistance is still within the maximum value for central office switching equipment without long line adapters. The amount of loop resistance added by each voice pass filter varies from approximately 4 ohms to 140 ohms depending upon the manufacturer and type of filter. Where voice pass filters are bridged on a line as in Figure 8, the total d.c. loop resistance to a particular subscriber's location contributed by filters is that of one voice pass filter plus a voice pass or line filter at the central office. Where an application is such that insertion type (voice pass) filters must be connected into a line the total d.c. loop resistance to a particular subscriber's location contributed by filters is that of one-half of one insertion filter plus that of any insertion filters at intermediate locations plus a voice pass or line filter at the central office. Situations will also arise where the use of line filters at intermediate locations will also add to the total d.c. loop resistance of the physical circuit. Manufacturer's

data concerning line and insertion type filters should be used for determining d.c. loop resistance values.

Net Subscriber Loop Loss

| | | | |
|---|---|---|---|
| 15.84 kf | (3 mi.) 109 Grade 135 steel wire x -0.031 db.kf | = | -0.49 db |
| 42.24 kf | (8 mi.) 080 CW 30 open wire x -0.067 db/kf | = | -2.83 db |
| 2.64 kf | (0.5 mi.) 22 gauge cable x 0.287 db/kf | = | +0.76 db |
| 60.72 kf | Uncorrected subscriber loop loss | = | -2.56 db |
| | Insertion loss at 1000 cps for two voice pass filters in series in addition to a possible maximum of nine unterminated voice pass filters shunting the subscriber loop | = | +2 db |
| | Entrance to central office | = | +0.5 db |
| | Net Subscriber Loop Loss | = | -0.06 db |

The value of net subscriber loop loss is within the 0 db effective limitations for subscriber loops even though voice pass filters were added in series with the subscriber line and the relative gain of the 5 db Improved Telephone Set to the Standard Telephone Set was not considered. The insertion loss value assumed in the calculation takes into account the insertion losses of two filters (one at the central office) plus the additional shunting losses of 9 unterminated filters in an application where a maximum of ten voice pass filters might be connected in a subscriber loop. This situation would occur where the party-line arrangement is such that a separate filter would be required for each subscriber's telephone. It is not expected that the insertion losses at 1000 cps will exceed two db in such arrangements with ten voice pass filters of any one manufacturer.

5.05 In all of the previous subscriber carrier applications shown herein it was assumed that the central office terminals of the carrier equipment were physically mounted within the central offices. Occasionally, application situations may arise whereby it is not practicable to mount these terminals within the central office. Such applications would be in situations where the cable attenuation at carrier frequencies is excessive, where all available cable pairs must be loaded in order to meet voice frequency transmission requirements for physical subscriber loops, or where there is known excessive carrier frequency crosstalk due to the cable facilities. Figure 9 is a one line diagram illustrating how the central office terminals of a subscriber carrier system can be mounted external to the central offices at a location such as the cable-open wire junction. Unlike certain types of trunk carrier system applications which require separate signaling leads for such an arrangement the subscriber carrier channels require only one pair per channel between the central office and the carrier terminals since they terminate in the central office in the same manner as physical subscriber loops.

5.051 Where the central office carrier terminals are mounted external to the central office the net subscriber loop loss for carrier subscribers can be computed in the same manner as illustrated in Paragraph 5.042 with the 1000 cps loss of the cable circuit facility added algebracially in the same manner as the central office entrance loss so that a net subscriber loop loss can be computed for the overall circuit. The d.c. loop resistance of the cable pair between the central office and the carrier terminal plus the d.c. loop resistance of the T and R leads of the central office terminal of the carrier channel when in an off-hook condition must not exceed the maximum loop resistance permissible for the central office switching equipment.

5.06 Figure 10 is an illustration of the use of carrier and voice pass filters to sectionalize a wire pair into two separate voice circuits while permitting the transmittal of carrier currents in both directions with a minimum of attenuation. A carrier pass filter is a high pass filter which permits the passage of carrier currents in both directions with a minimum attenuation while providing high attenuation for ringing and voice frequencies. Direct currents are blocked

by such a filter. By inserting a carrier pass filter (Fc) into the wire pair as shown in Figure 10 it is possible to provide two distinct physical circuits. One of these circuits connects with the central office in the normal manner while the other connects with the voice frequency drop of subscriber carrier channel 2. Depending upon the economics in such an application situation it may be more practicable to utilize a carrier pass filter as shown rather than construct a separate wire pair along the same route for connecting party line subscribers served by subscriber carrier channel 2. The voice pass filter shown at the subscriber terminal prevents carrier currents of channels 1 and 2 from being attenuated by the voice frequency drop of carrier channel 2. The other voice pass filters are connected in the normal manner.

5.07 Numerous subscriber carrier applications arise where subscriber terminals are connected to the carrier line at separate locations. Examples of such arrangements were shown in previous Figures. Figure 11 is an example where subscriber terminals for channels 3 and 4 are mounted in a different location than that of channels 1 and 2. In order to prevent additional carrier frequency transmission losses a line filter consisting of a low pass and a high pass section is inserted in the line as shown. The low pass section has a cutoff frequency somewhat above channel 2 and prevents additional transmission losses to carrier channels 3 and 4 due to the tap represented by the carrier wire pair connecting to channels 1 and 2. Similarly, the high pass section has a cutoff frequency somewhat below channel 3 and prevents additional transmission losses to carrier channels 1 and 2 due to the tap represented by the carrier wire pair connecting to channels 3 and 4.

A bandpass filter arrangement is also utilized in some applications for similar reasons. Various other line filter combinations can be installed along a carrier route so that one or more channels can be dropped at separate locations in order to efficiently serve subscribers with a minimum number of wire pairs.

5.071 In Figure 11 it can be seen that the high pass filter also performs the functions of the carrier pass filter described in Paragraph 5.06, therefore, the wire pair between this filter location and the channel 4 subscriber terminal can usually be utilized for connecting party line subscribers. The same arrangement cannot be utilized for the wire pair between the low pass filter and either channels 1 and 2 since this filter does not provide D.C. blocking or sufficient voice frequency attenuation for the 8 physical subscribers connected adjacent to the central office. If it is planned to utilize the portion of the route between the low pass filter location and channels 1 and 2 for connecting party line subscribers a carrier pass filter as described in Paragraph 5.06 should also be provided.

## 6. CROSSTALK CONSIDERATIONS

6.01 In open wire carrier system applications it is necessary that a transposition system be selected which will permit the use of a sufficient number of carrier channels on one or more wire pairs in order to meet initial and future requirements of the carrier application. The R1, R2, REA-1 and REA-VI transposition systems can be utilized within their limits for carrier systems of various types and frequency ranges. Data on the maximum frequency ranges and pair assignments for these transposition systems from the standpoint of crosstalk loss and absorption peaks can be found in the REA-TE & CM-Sections 462, 463 and 465.

## 7. ELECTRICAL PROTECTION

7.01 Detailed information for providing the proper type of electrical protection to subscriber carrier terminals and filters can be obtained in the REA-TE & CM Section 822 and in applications manuals provided by various carrier equipment suppliers. Due to the cost of filters of various types and the extensive use of these filters to provide economical circuit arrangements when used with subscriber carrier equipment it is necessary to provide proper protection devices at all filter locations. It is also extremely important that all subscriber carrier terminal equipment be protected in accordance with applicable recommendations.

## 8. CARRIER MAINTENANCE AND TROUBLE SHOOTING

8.01 Maintenance and trouble shooting procedures for subscriber carrier equipment vary due to the dissimilarity of equipment of different manufacturers. These various types of equipment differ primarily in their modulating techniques, the manner in which on-hook and off-hook signals, dialing, and ringing information are transmitted and received over the carrier system, whether bridged for full selective ringing is provided, the number of test jacks and the methods in which carrier terminals are assembled from one or more chassis, plug-in subassemblies, etc. Manufacturers' recommendations as described in their equipment manuals should therefore be followed by maintenance personnel.

8.02 The annual charges developed for carrier terminals as listed in the REA-TE & CM Section 218 include costs for making several trips per year to carrier terminal locations for purposes of maintenance and trouble shooting. These annual charges also include replacement of vacuum tubes (the number of tubes replaced usually varies depending upon whether they are commercial or industrial types and their use in particular circuits) and power consumption costs. Annual charges will be influenced by the number of separate carrier terminal locations to which trips have to be made as well as the power consumption costs at each separate location. As mentioned earlier it is advantageous from the standpoints of maintenance and power consumption to minimize the number of separate carrier terminal locations.

8.03 Subscriber carrier manufacturers are designing their equipment to provide long vacuum tube life by operating the tubes well within their maximum ratings. In addition, some types of equipment utilize either commercial or industrial tube types interchangeably since industrial tube types may provide longer life in some situations.

8.031 As a further aid in improving vacuum tube reliability various carrier manufacturers operate their vacuum tubes for a "run-in" period prior to installing them in carrier equipment since many defective vacuum tubes seem to fail within their first several weeks of operation.

8.032 Some carrier manufacturers feel that vacuum tubes known to be good should be substituted for vacuum tubes suspected of being defective rather than using a tube tester for locating defective tubes. Even though some tube testers may indicate that a particular tube is weak the tube may still function properly in carrier equipment for a substantial period.

8.033 To assure long vacuum tube life the proper type of AC line voltage regulators should be used at carrier equipment installations which are powered from alternating current sources if the line voltage variations are in excess of the limits prescribed by the various carrier manufacturers for the proper functioning of their equipment.

8.04 As an aid in maintaining and trouble shooting subscriber carrier equipment manufacturers have provided test points at various locations on the chassis so that important voltages can be read periodically as an indication of the performance of the various circuits in the carrier equipment. These test points are usually located in such a manner that indications of transmitter output, receiver input, detector output, signaling relay voltages, etc., can be conveniently determined from the front of the carrier terminal. It is important that the test point readings be recorded whenever the carrier equipment is installed and functioning properly and then rechecked at periodic intervals for preventative maintenance purposes or as a guide in trouble shooting.

8.041 Some manufacturers have located these test points in circuits in a manner so that multimeters, such as the Simpson Model 260 or equivalent, can be utilized for most of the required measurements at the terminals.

8.042 Other desirable types of test equipment useful for carrier testing and maintenance are oscillators which cover both the voice and carrier frequency ranges and vacuum tube voltmeters which read sufficiently low values of voltage so that voice frequency net losses can be accurately adjusted.

8.043 Some types of carrier equipment are provided with test points which require the use of an AC vacuum tube voltmeter capable of reading small voltages such as 0.077 volts, for example, which corresponds

to a power of -20 dbm when read across a 600 ohm resistance load. Ordinary vacuum tube voltmeters which read AC volts, DC volts and ohms are not suitable for this type of reading.

8.05 Subscriber carrier instruction manuals presently available usually contain a section listing some typical troubles encountered and the proper means for correcting them in particular types of equipment. In addition to troubles which may develop at central office or subscriber terminal locations reported carrier troubles may be due to various voice pass or other types of filters inserted in the carrier line at locations intermediate to the terminal equipment, the wire pair with its various protectors which links the carrier terminals, the voice frequency drops connected to the subscriber or central office terminals, the telephone sets and their ringers connected to these voice frequency drops, and the central office switching equipment.

8.051 The following paragraphs describe some of the typical reported troubles and their causes as they apply to any type of subscriber carrier equipment. Some of these troubles have no counterpart in trunk carrier equipment and result from the necessarily different signaling arrangements which must be provided in subscriber carrier systems. Figures 12 and 13 show in schematic form the various portions of the carrier equipment or other items of telephone plant which could be causing reported troubles. In situations where more than one portion of the carrier channel or item of plant might be causing the reported trouble the possible causes of trouble are listed in a logical order starting at the central office and working in the direction toward the subscriber terminal. This order of trouble shooting would save travel time to subscriber terminals in many situations where the trouble may exist at the central office end of the carrier circuit.

8.052 Carrier channels completely inoperative in both directions of transmission.

8.0521 A report that calls cannot be made to or received from subscribers connected to the voice frequency drop of a subscriber carrier channel and this channel is providing an off-hook condition to the central office switching equipment. The carrier channel is of a type which normally provides tone or carrier off when in the idle condition in the direction of transmission from the subscriber terminal to the central office terminal——

8.05211 The central office line connected to the voice frequency drop of the central office terminal of the carrier channel may be defective. Making a test call from this line into the central office equipment with the carrier voice drop disconnected should quickly prove whether the central office circuit is defective.

8.05212 The central office terminal of the carrier channel may not have power supplied to it.

8.05213 The power fuse for this terminal may have blown.

8.05214 The receive signaling circuit at the central office carrier terminal may be defective.

8.05215 The voice frequency drop connected to the subscriber terminal of the carrier system may be short circuited.

8.05216 The ring side of this voice frequency drop may be grounded somewhere along its route.

8.05217 A telephone set connected to this subscriber drop may accidentally be in an off-hook condition or its ringer may be defective.

8.0522 A report that calls cannot be made to or received from subscribers connected to the voice frequency drop of a subscriber carrier channel and this channel is providing an off-hook condition to the central office switching equipment. The carrier channel is of a type which normally provides tone or carrier on when in the idle condition in the direction of transmission from the subscriber terminal to the central office terminal:—

8.05221 The central office line connected to the voice frequency drop of the central office terminal of the carrier channel may be defective. Making a test call from this line into the central office equipment with the carrier voice drop disconnected should quickly prove whether the central office circuit is defective.

8.05222 The central office terminal of the carrier channel may not have power supplied to it.

8.05223 The power fuse for this terminal may have blown.

8.05224 The receive signaling circuit at the central office carrier terminal may be defective.

8.05225 The wire pair linking the carrier terminals may be defective. A test call made to another subscriber terminal mounted at the same location should quickly determine if the carrier line is defective providing that a.c. power is being supplied at the remote terminals and the other carrier channels are functioning satisfactorily.

8.05226 The a.c. power at the subscriber terminal may have failed. A test call made to another subscriber terminal mounted at the same location should quickly determine if power is being supplied at this location.

8.05227 The power fuse for the subscriber terminal may have blown. A test call to another channel terminal mounted at the same location should quickly determine if the fuse is blown or a.c. power is off to all channels, assuming that the wire pair linking the carrier channels is not defective and that the other carrier channels are not defective simultaneously.

8.05228 The tone or carrier frequency transmitter at the subscriber terminal may be defective.

8.05229 The possible troubles to the voice frequency drop or the telephone set as described in 8.05215, 8.05216 and 8.05217 could be occuring.

8.0523 A report that calls cannot be made to or received from subscribers connected to the voice frequency drop of a subscriber carrier channel and this channel is providing an on-hook condition to the central office switching equipment. The carrier channel is of a type which provides tone or carrier off when in the idle condition in the direction of transmission from the subscriber terminal to the central office terminal——

8.05231 The central office line connected to the voice frequency drop of the central office terminal of the carrier channel may be defective. Making a test call from this line into the central office equipment with the carrier voice drop disconnected should quickly prove whether the central office circuit is defective.

8.05232 The receive signaling circuit or carrier receiver at the central office terminal of the carrier channel may be defective.

8.05233 The wire pair linking the carrier terminals may be defective. Calling a subscriber connected to another subscriber terminal at this location should determine if the wire pair is defective.

8.05234 The transmit signaling circuit or carrier transmitter at the subscriber terminal may be defective.

8.05235 The a.c. power at the subscriber terminal may have failed.

8.05236 The power fuse at this subscriber terminal may have failed. Test calls to subscribers connected to another channel terminal at this location should be used to try to determine if the fuse has blown or the condition described in 8.05235 has taken place.

8.05237 The voice frequency drop from the subscriber terminal may be open at the station protector mounted at the carrier terminal or at another location along its route.

8.0524 A report that calls cannot be made to or received from subscribers connected to the voice frequency drop of a subscriber carrier channel and the channel is providing an on-hook condition to the central office switching equipment. The carrier channel is of a type which provides tone or carrier on when in the idle condition in the direction of transmission from the subscriber terminal to the central office terminal——

8.05241 The central office line connected to the voice frequency drop of the central office terminal of the carrier channel may be defective. Making a test call from this line into the central office equipment with the carrier voice drop disconnected should quickly prove whether the central office circuit is defective.

8.05242 The voice frequency drop from the subscriber terminal may be open at the station protector mounted at the carrier terminal or at another location along its route.

8.053 Ringing Difficulties

8.0531 A report that ringing to a particular carrier subscriber on a full selective ringing system is being received by another subscriber whose ringer is of the same frequency but connected between the opposite side of the line and ground——

8.05311 The central office equipment is not supplying ringing power between the proper side of the line and ground. Making a test call to this line from the central office telephone and measuring the ringing output should quickly prove whether the ringing power is being applied properly.

8.05312 The side-of-the-line selection equipment in the central office terminal of the carrier channel is not functioning properly.

8.05313 The side-of-the-line selection equipment in the subscriber terminal of the carrier channel is not functioning properly and the relay associated with this circuit is not being switched to place ringing voltage and ground on the proper side of the line in accordance with the number dialed.

8.05314 When the trouble is caused by the side-of-the-line selection equipment in the carrier channels the carrier circuits for deriving ringing power of the proper frequency and applying it to the voice frequency drop of the carrier channel may function properly and trouble shooting of these circuits probably would not be necessary.

8.0532 A report that it is not possible to ring a particular subscriber connected to the voice frequency drop of a subscriber carrier channel——

8.05321 The central office may not be applying ringing power of the proper frequency between one side of the line and ground at the central office terminal of the carrier channel. Making a test call to this line from the central office telephone and measuring the ringing output should quickly prove whether the ringing power is being applied properly.

8.05322 The side-of-the-line selection difficulties for the carrier channel as described in 8.05312 and 8.05313 may be occurring.

8.05323 An open bridle wire, drop wire or fuse in the telephone circuit of the particular subscriber reporting the difficulty may have occurred.

8.05324 A defective ringer in the telephone set may be the cause of the difficulty.

8.05325 A sufficient number of loud ringing bells or extension telephones with their ringers connected may be installed at the particular subscriber's residence so that ringing power output of the carrier channel at a particular frequency is substantially reduced by the heavy ringing load.

8.05326 Test calls made to other subscribers whose ringers are connected between both tip and ring sides of the line and ground should be made from the central office to determine if the carrier channel itself is causing the difficulty.

8.0533 A report that difficulty is being experienced in ringing subscribers connected to the voice frequency drop of a subscriber terminal whose ringers are connected between either the tip or ring sides of the line and ground and in the frequency range between 50 and 66 c.p.s.——

8.05331 In some situations this difficulty may be due to connecting Western Electric Company's Type 108A Protector Units or the equivalent on the voice frequency drop of the carrier channel since these units provide a relatively low impedance path to ground for the tip and ring leads in the range of the 60 c.p.s. frequency.

8.0534 A report that ringing to a called subscriber on a full selective ringing system is being received by another subscriber whose ringer is of a different frequency (cross ringing) but connected between the same side of the line and ground or where other than the called subscriber's ringer is actuated (cross ringing) on a full selective bridged (five party) ringing system——

8.05341 The power output of the central office ringing generator may have drifted in frequency.

8.05342 The waveshape of the ringing power output at the subscriber terminal of the carrier channel may be distorted and thereby produce the harmonics which are causing cross ringing.

8.05343 The ringing power output control of the carrier system (only present on certain types of carrier systems) may be improperly adjusted. The carrier manufacturer's recommendations for the setting of this control or other techniques for minimizing cross ringing should be followed.

8.05344 The particular ringer which is responding to power of a different fundamental frequency may be out of adjustment. Making a test call to a subscriber whose telephone has a similar ringing frequency but is connected between the opposite side of the line and ground should prove whether the particular ringer is out of adjustment or whether the carrier system itself or the ringing generator might be causing the cross ringing.

8.05345 For all of the cross ringing complaints the side of the line selection equipment in the carrier terminals and the ringing relay which applies power to the voice drop are probably functioning normally.

8.0535 A report that it is possible to dial properly and talk in both directions of transmission from the voice frequency drop of a subscriber carrier terminal but that it is impossible to ring subscribers connected to this voice frequency drop (revertive calls) or that subscribers connected to other lines cannot ring subscribers connected to this voice frequency drop——

8.05351 The revertive call equipment or the central office equipment which supplies ringing power of the proper frequency between the proper side of the line and ground may not be

functioning properly and is not supplying ringing information to the central office terminal of the carrier channel. A test call made from the telephone in the central office should quickly prove whether or not this equipment is working properly on through calls while a revertive test call made from the voice frequency drop of the central office terminal of the carrier should quickly prove whether or not the revertive call equipment is functioning properly.

8.05352 The ringing circuits in the central office terminal of the carrier channel may be defective.

8.05353 The ringing circuits in the subscriber terminal of the carrier channel may be defective. The defect could be one where the terminal is not generating any ringing power or that the generated ringing power is not being applied to the voice frequency drop by the ringing output relay.

8.05354 On full selective ringing systems the ground connection for the ringing output power might not be supplied by the side-of-the-line selection relay in the subscriber terminal during the ringing condition.

8.054 Dialing Difficulties

8.0541 A report that it is possible to properly ring and talk with subscribers connected to the voice frequency drop of a subscriber terminal of a carrier channel but that these subscribers cannot dial other subscribers on their own line (revertive calls) or those on other lines in the telephone system——

8.05411 The central office circuit connected to the voice frequency drop of the central office terminal of the carrier channel for either through or revertive calls may be defective. Making a through or revertive call from the voice frequency drop of this carrier terminal should prove whether or not the dialing operation is functioning properly.

8.05412 The receive signaling circuit associated with the central office terminal of the carrier channel may be defective.

8.05413 The transmit signaling circuit associated with the subscriber terminal of the carrier channel may be defective.

8.05414 If it is suspected that only one subscriber is having dialing difficulties as compared with several other subscribers on the same party line the dial of this particular subscriber's telephone may not be adjusted properly. Calling other party line subscribers and requesting them to dial the central office telephone should quickly prove whether a particular dial or the carrier equipment itself is causing the difficulty.

8.055 Talking Failures in One Direction of Transmission

8.0551 A report that it is possible to properly ring and talk to called party line subscribers connected to the voice frequency drop of a subscriber carrier channel but they cannot be heard by calling subscribers. The carrier subscribers can properly dial other lines in the telephone system———

8.05511 The voice frequency circuits associated with the carrier receiver at the central office terminal may be defective.

8.05512 The voice frequency circuits associated with the carrier transmitter at the subscriber terminal may be defective.

8.05513 If it is suspected that only one called party cannot be heard by the calling party as compared with several other subscribers on the same party line the transmitter in the called party's telephone set may be defective. Calling other subscribers on this same party line can quickly determine whether the difficulty is in the carrier equipment or the telephone transmitter.

8.0552 A report that it is possible to properly ring and talk to called party line subscribers connected to the voice frequency drop of a subscriber carrier channel but they cannot be heard by calling subscribers. The carrier subscribers cannot properly dial other lines in the telephone system——

8.05521 The carrier receiver at the central office terminal may be defective.

8.05522 The carrier transmitter at the subscriber terminal may be defective.

8.0553 A report that it is possible to properly dial and talk from the voice frequency drop of a subscriber carrier channel but that the calling party cannot hear the called party——

8.05531 The transmitter in the called party's telephone set may be defective. Since the calling party was able to seize the central office switching equipment, receive dial tone and properly dial over the carrier system it is probably functioning satisfactorily in both directions of transmission.

8.0554 A report that it is impossible to receive dial tone at the voice frequency drop of a subscriber terminal although placing a telephone connected to this drop in the off-hook condition seizes the central office equipment——

8.05541 The carrier transmitter itself or the voice circuits associated with it at the central office terminal of the carrier channel may be defective.

8.05542 The carrier receiver itself or the voice circuits associated with it at the subscriber terminal of the carrier channel may be defective.

8.05543 If it is suspected that only one calling party cannot hear the dial tone as compared with the other party line subscribers connected to the carrier drop the receiver in the calling party's telephone set may be defective. Attempted calls to other party line subscribers connected to this drop could be made to determine if the carrier equipment or the telephone receiver is defective.

8.056 Carrier Transmission Difficulties

8.0561 A report that a subscriber carrier channel sounds "hollow" or that singing occurs on certain through or revertive calls——

8.05611 The voice frequency gain control or controls which determine the voice frequency net loss at which the carrier channel operates are probably not adjusted in accordance with the carrier manufacturers' recommendations for one or both directions of transmission.

8.0562 A report that the carrier frequency attenuation of the wire pair connecting the carrier terminals is substantially greater than calculated wet weather values at certain carrier frequencies——

8.05621 One or more of the carrier line filters installed on the wire pair may be defective.

8.05622 An absorption peak can be occurring on the open wire pair if the carrier frequencies are in excess of the maximum frequencies for which the transposition system was designed.

8.05623 One or more Western Electric Company's 108A Protectors or the equivalent, could have been connected between the carrier wire pair and ground without treating them properly for carrier frequency operation.

8.05624 One or more voice pass filters could have been connected to the wire pair with their connections reversed. (Voice frequency drop side of the filter connected to the carrier wire pair and carrier line side connected to the voice frequency drop).

8.05625 A new subscriber tap could have been added to the carrier wire pair without inserting a voice pass filter between the tap and the carrier line.

8.05626 Cable branches or laterals may be connected to the through cable pair without inserting voice pass filters at the junction of these cable pairs.

8.05627 A new carrier tap could have been added to the wire pair for connecting one or more additional carrier channels without inserting the proper type of carrier filter or filters between the new tap and the main wire line route.

8.05628 An increase in leakage between conductors of the carrier wire pair and between these conductors and ground as a result of foliage growing into the carrier wire pair, dirty or shorted carbon blocks in the various protectors connected to this wire pair, defective insulators, structural defects, etc.

8.05629 One or more of the voice pass filters have the wrong cutoff frequency for the particular channels utilized. (Par.5.024

8.057 Noise Problems

8.0571 A report that one or more carrier channels have had their transmission impaired due to noise. Since this noise can be caused by amplified and detected carrier frequency noise on the wire pair linking the carrier terminals or voice frequency noise resulting from various conditions of unbalance on the voice frequency drop a simple test should be made to determine which type of noise is causing the transmission impairment. If the voice frequency drop at the subscriber terminal is temporarily disconnected while a test call is made from this location to the central office telephone and the noise is no longer present the noise is at voice frequencies and its cause can be determined by a procedure similar to that used for subscriber lines which is outlined in REA-TE & CM Section 45! If the test call reveals that the noise still persists with the voice drop removed it is amplified carrier noise and could be due to any of the following conditions——

8.05711 Any of the conditions outlined in 8.0562 which are causing substantially greater attenuation at carrier frequencies than the expected wet weather values.

8.05712 By installing the carrier channel on a wire pair whose attenuation at carrier frequencies exceeds the recommended maximum value of the manufacturer for a particular type of subscriber carrier equipment.

8.05713 The power output of the carrier transmitters at one or both carrier terminals may have decreased due to tube aging, etc. If the noise is objectionable in only one direction of transmission the transmitter of the carrier terminal for this direction of transmission may have decreased its output power.

8.05714 The carbon blocks on various protectors may be breaking down and causing carrier frequency noise.

8.05715 Corroded splices in the open wire or cable portions of the circuit.

8.058 Voice Pass Filter Problems

8.0581 A report that the physical subscriber line upon which the subscriber carrier system is superimposed shows an off-hook condition while the subscriber carrier channels are functioning properly——

8.05811 The capacitor of a voice pass filter connected across the tip and ring leads is short circuiting due to lightning damage or other causes.

8.05812 The physical wire pair between a voice pass filter location and a physical subscriber's telephone set is accidentally short circuiting or the ring side of the line is accidentally grounded.

8.05813 A telephone set at a physical subscriber's residence has accidentally been placed in an off-hook condition.

8.0582 A report that one or more physical subscribers connected to a wire pair upon which subscriber carrier channels are superimposed and functioning properly are having difficulty in dialing correct numbers——

8.05821 The central office line associated with the physical subscribers may not be functioning properly. Making a test call from this line at the mainframe with the outside physical line disconnected should quickly prove whether it is functioning properly.

8.05822 The resistance of the inductor windings in the voice pass or line filter located at the central office or voice pass filters located at subscribers' taps may have increased substantially due to lightning or other causes so that the overall loop resistance of the physical circuit may be beyond the maximum value recommended for the particular central office. (Par. 5.043).

8.05823 The normal resistance of the inductor windings in the voice pass filter might have increased the loop resistance for the furthermost physical subscribers to such an extent that the loop resistance may be beyond the maximum value recommended for the particular central office.

8.05824 The capacitors associated with the voice pass filters which are connected across the tip and ring leads may be leaky due to lightning damage or other causes thereby causing distortion of dial pulses.

8.05825 The dial of the telephone set of the particular subscriber which reported the dialing difficulty may not be adjusted properly. A test call to other physical subscribers should reveal whether the dialing difficulty is common to all subscribers or to a particular subscriber.

8.0583 A report that it is impossible to call or receive calls from a physical subscriber that utilizes portions of the same wire line upon which subscriber carrier channels are superimposed. The subscriber carrier channels are functioning properly and the physical circuit shows an on-hook condition——

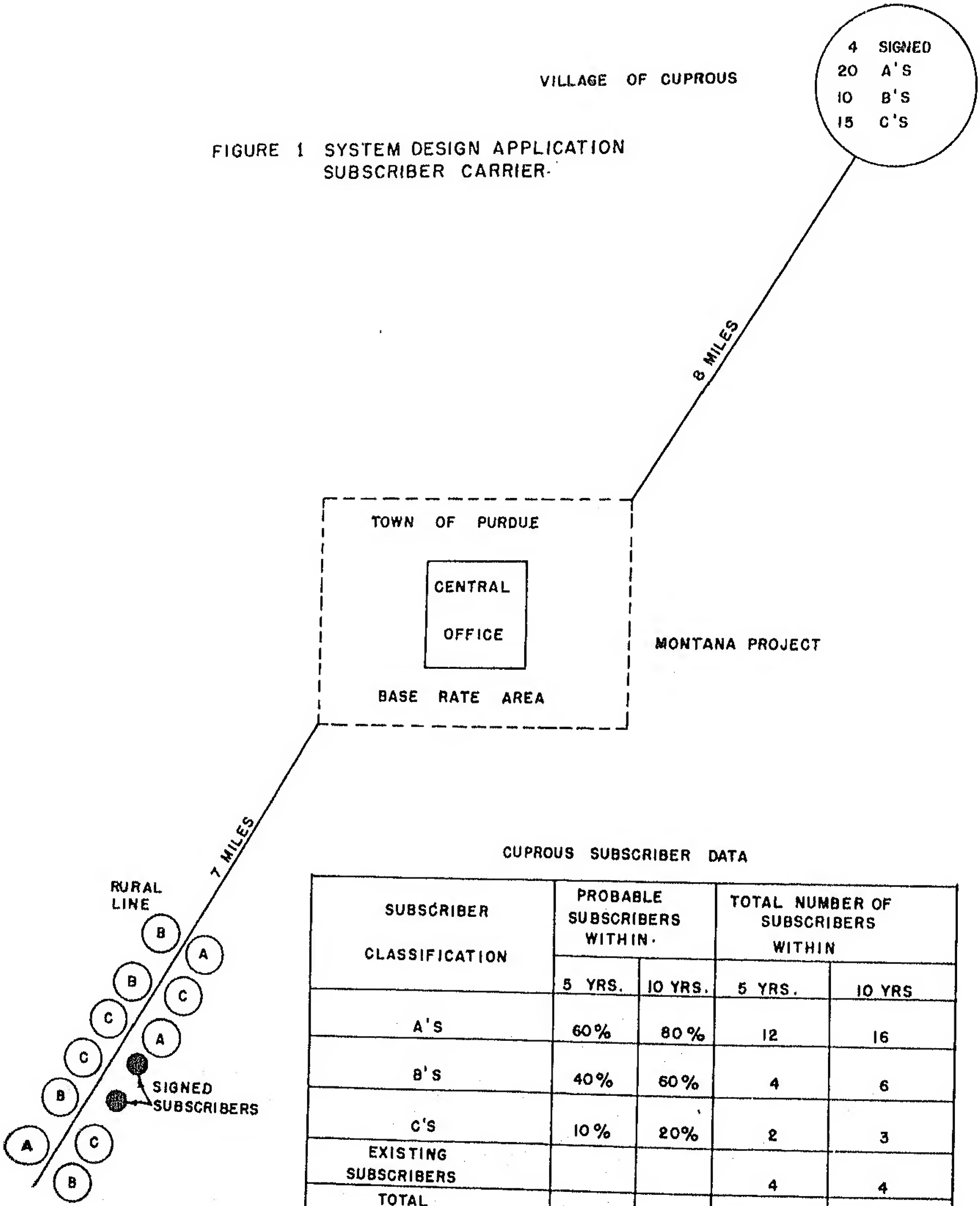
8.05831 The inductors of the voice pass filter connected at the subscriber tap are open due to lightning or other causes.

8.05832 The wire pair between the voice pass filter and the subscriber's telephone set is open.

8.05833 One or both fuses in the telephone station protectors at a physical subscriber's residence are open.

8.05834 The telephone set at the particular subscriber's residence is defective. If other subscribers are connected to this same voice frequency tap a test call made to these other subscribers should quickly prove whether the difficulty is due to the troubles given above.

FIGURE 1 SYSTEM DESIGN APPLICATION
SUBSCRIBER CARRIER




CUPROUS SUBSCRIBER DATA

| SUBSCRIBER CLASSIFICATION | PROBABLE SUBSCRIBERS WITHIN· | | TOTAL NUMBER OF SUBSCRIBERS WITHIN | |
|---|---|---|---|---|
| | 5 YRS. | 10 YRS. | 5 YRS. | 10 YRS |
| A'S | 60% | 80% | 12 | 16 |
| B'S | 40% | 60% | 4 | 6 |
| C'S | 10% | 20% | 2 | 3 |
| EXISTING SUBSCRIBERS | | | 4 | 4 |
| TOTAL SUBSCRIBERS | | | 22 | 29 |

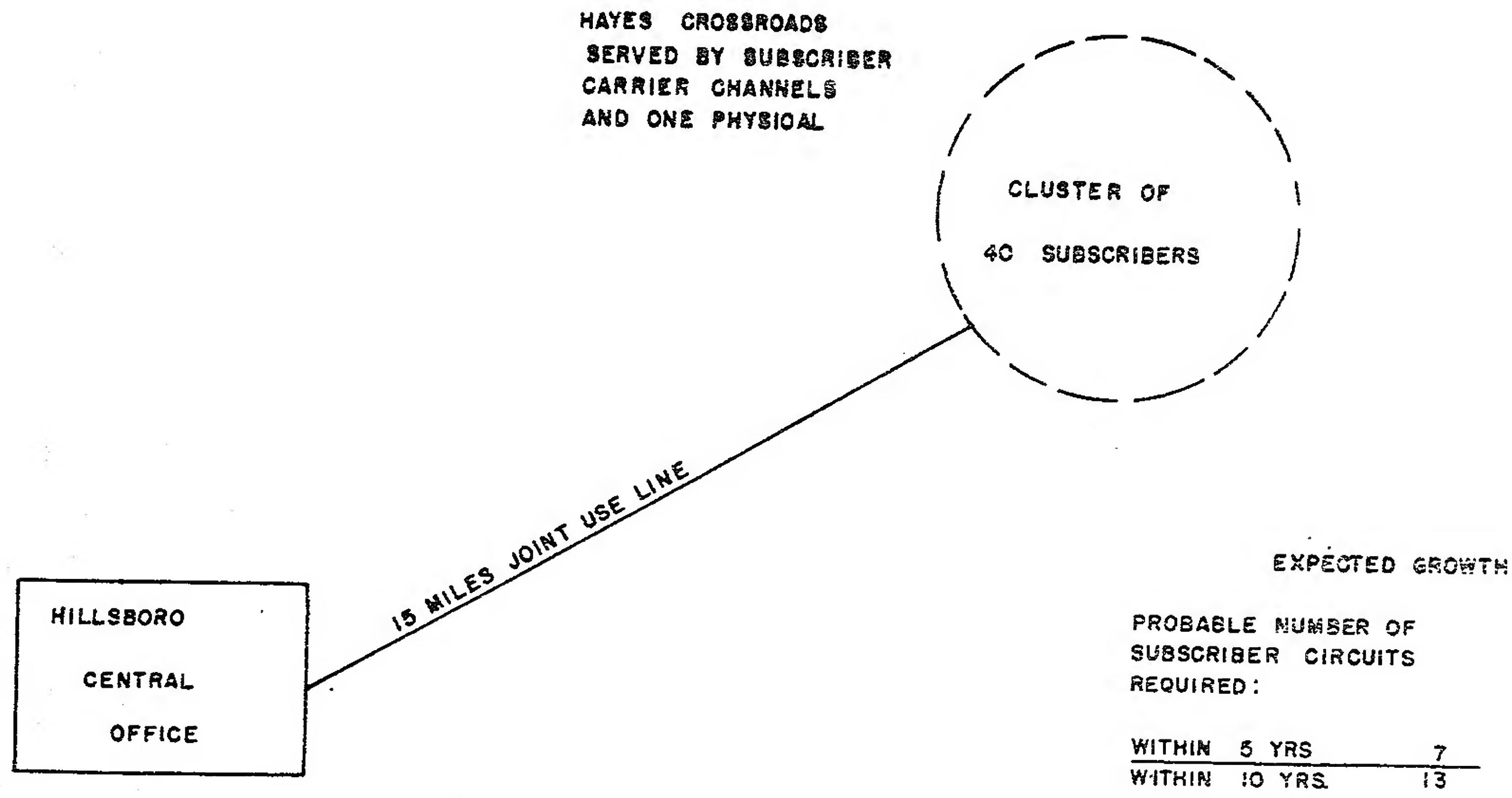



FIGURE 2 POSTPONING THE CONSTRUCTION OF, OR ELIMINATION OF A SMALL COMMUNITY DIAL OFFICE. NUMBERING SCHEME ALSO SIMPLIFIED.

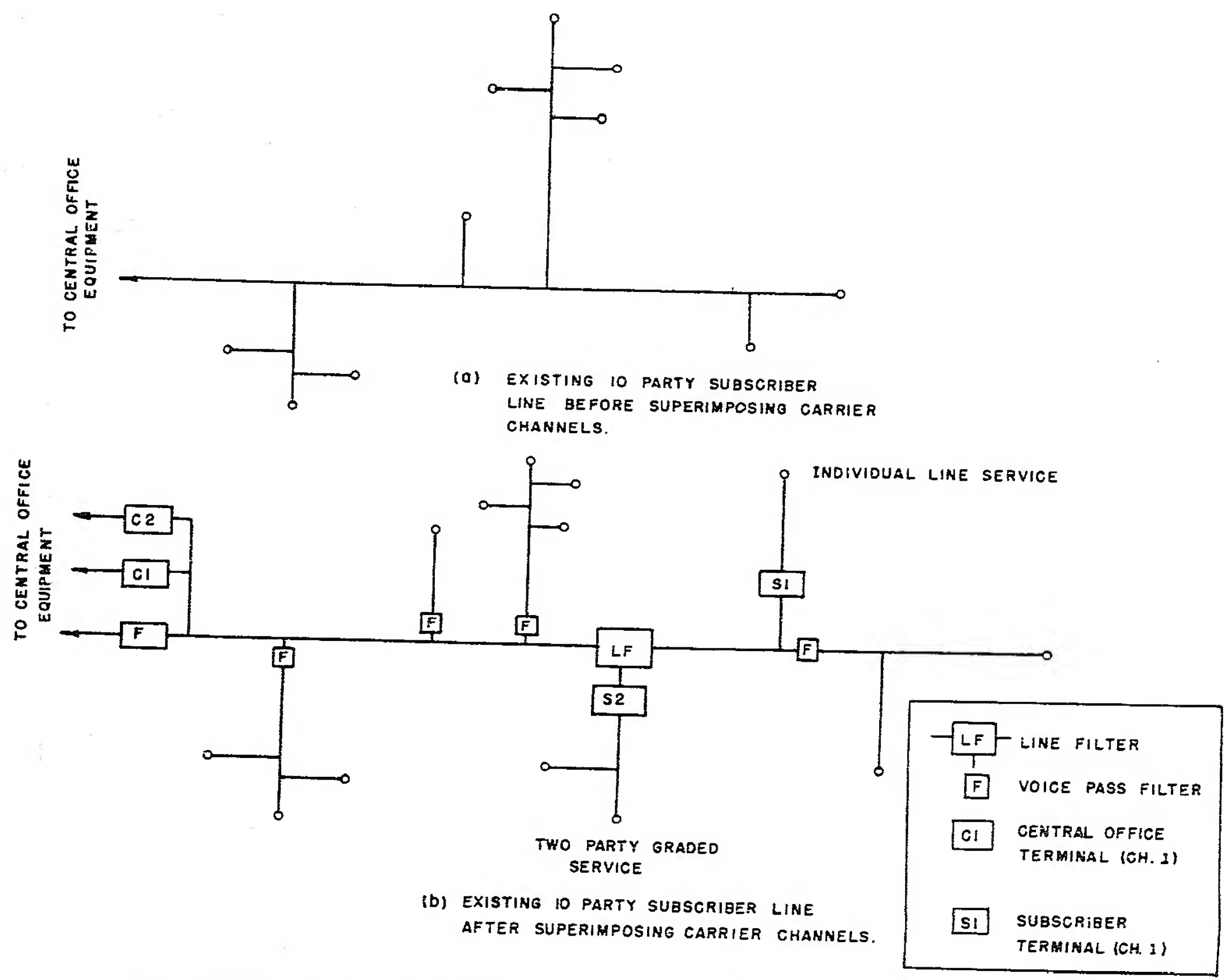
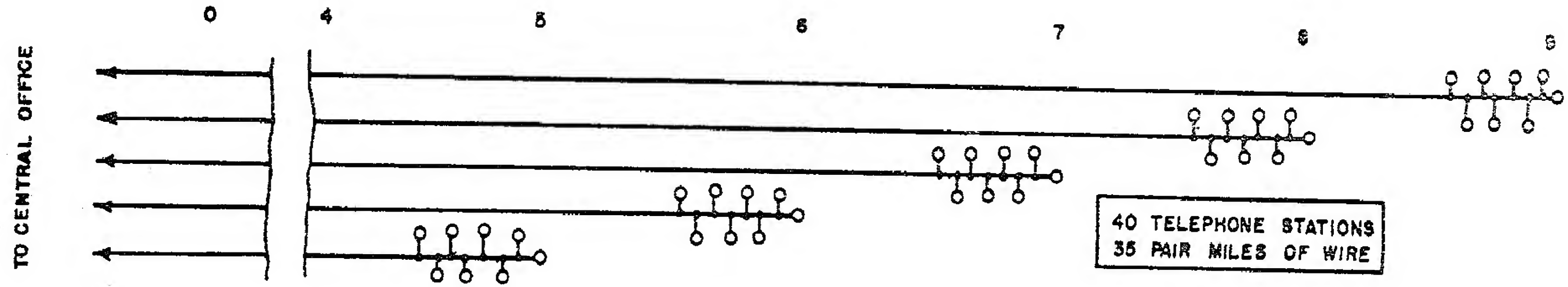
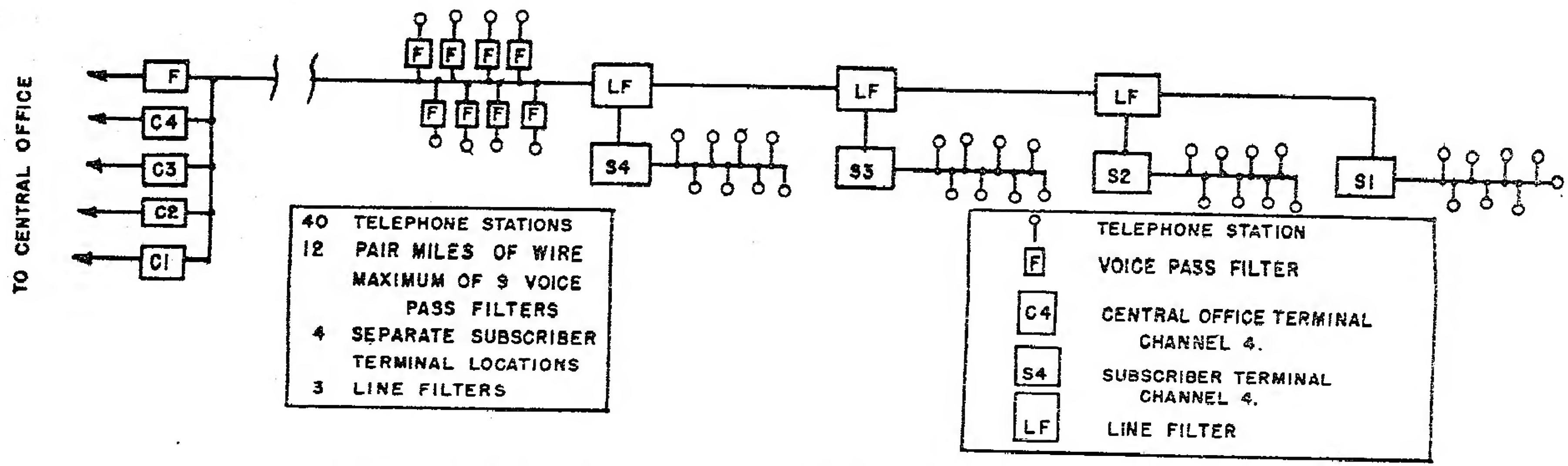



FIGURE 3 PROVISION OF TWO-PARTY GRADED SERVICE AND INDIVIDUAL LINE SERVICE BY MEANS OF SUBSCRIBER CARRIER CHANNELS SUPERIMPOSED ON AN EXISTING 10 PARTY LINE.




(a) 8 SUBSCRIBERS PER WIRE PAIR ON A CONVENTIONAL BASIS.




(b) 8 SUBSCRIBERS SERVED BY PHYSICAL CIRCUIT, 8 SUBSCRIBERS SERVED BY EACH CARRIER CHANNEL. SUBSCRIBERS SERVED BY MEANS OF CARRIER CHANNELS ARE CONNECTED TO SUBSCRIBER TERMINALS BY SEPARATE WIRE PAIRS.

FIGURE 4 POSSIBLE SUBSCRIBER CARRIER LAYOUTS ON A MULTI-PARTY BASIS

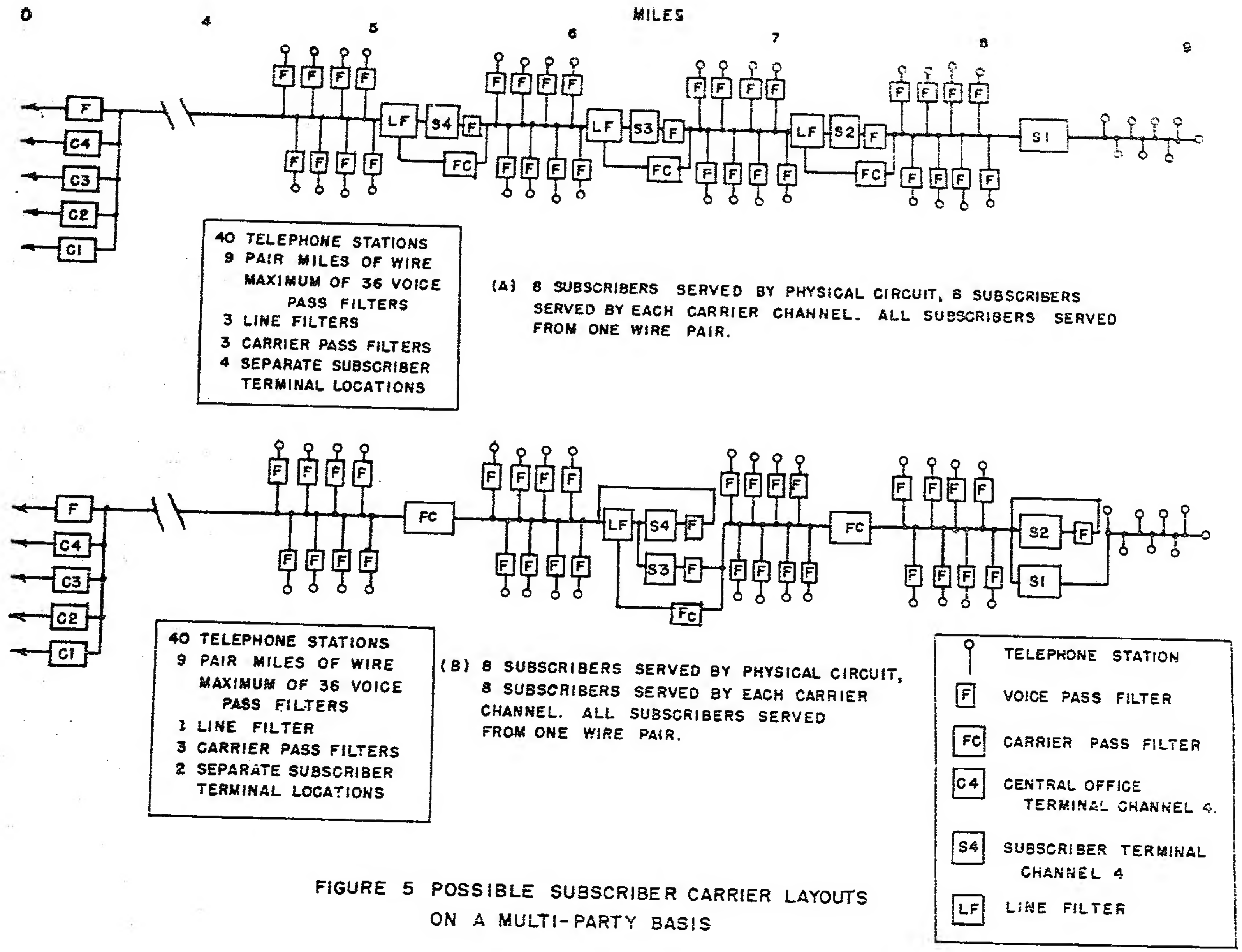



FIGURE 5 POSSIBLE SUBSCRIBER CARRIER LAYOUTS ON A MULTI-PARTY BASIS

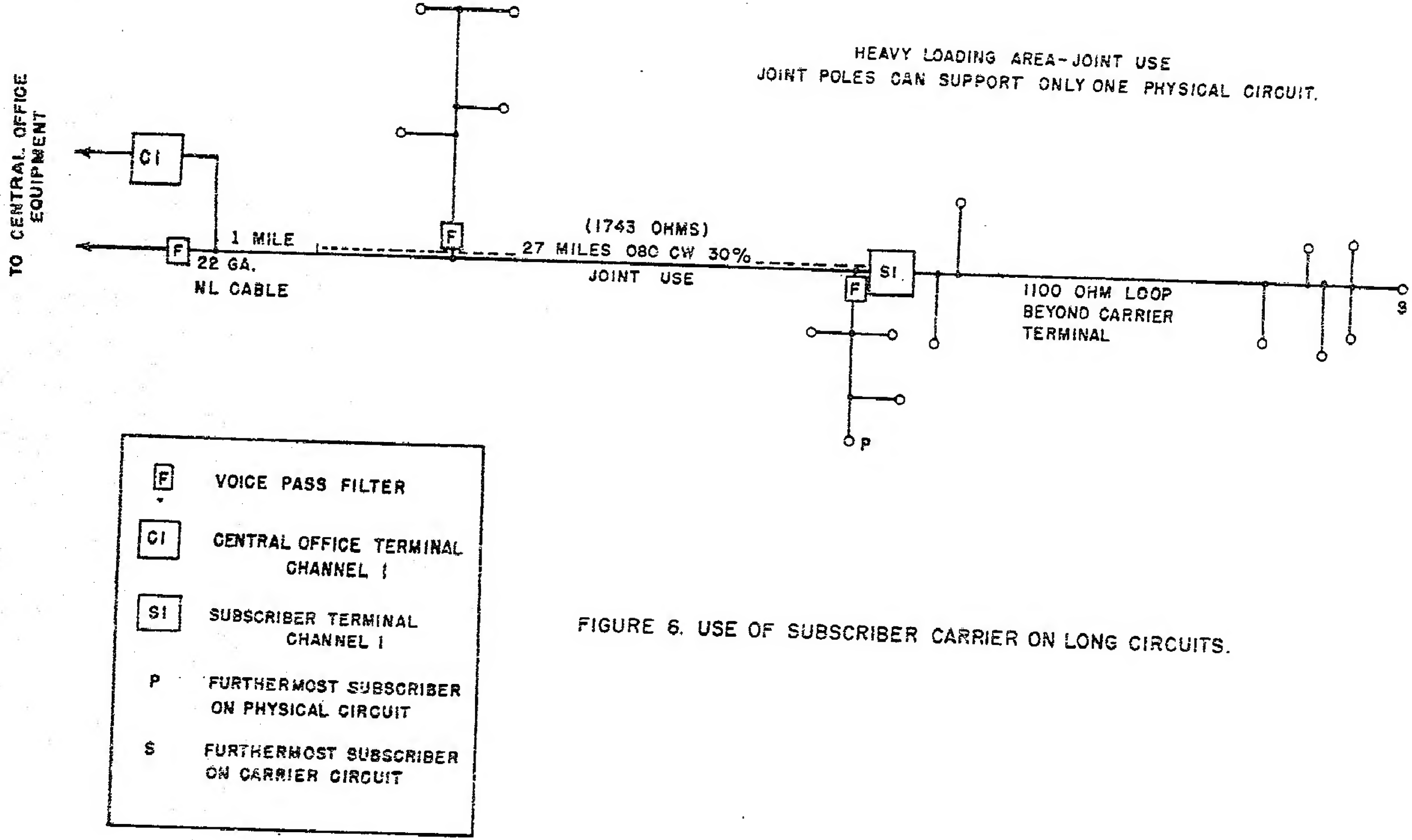



FIGURE 6. USE OF SUBSCRIBER CARRIER ON LONG CIRCUITS.

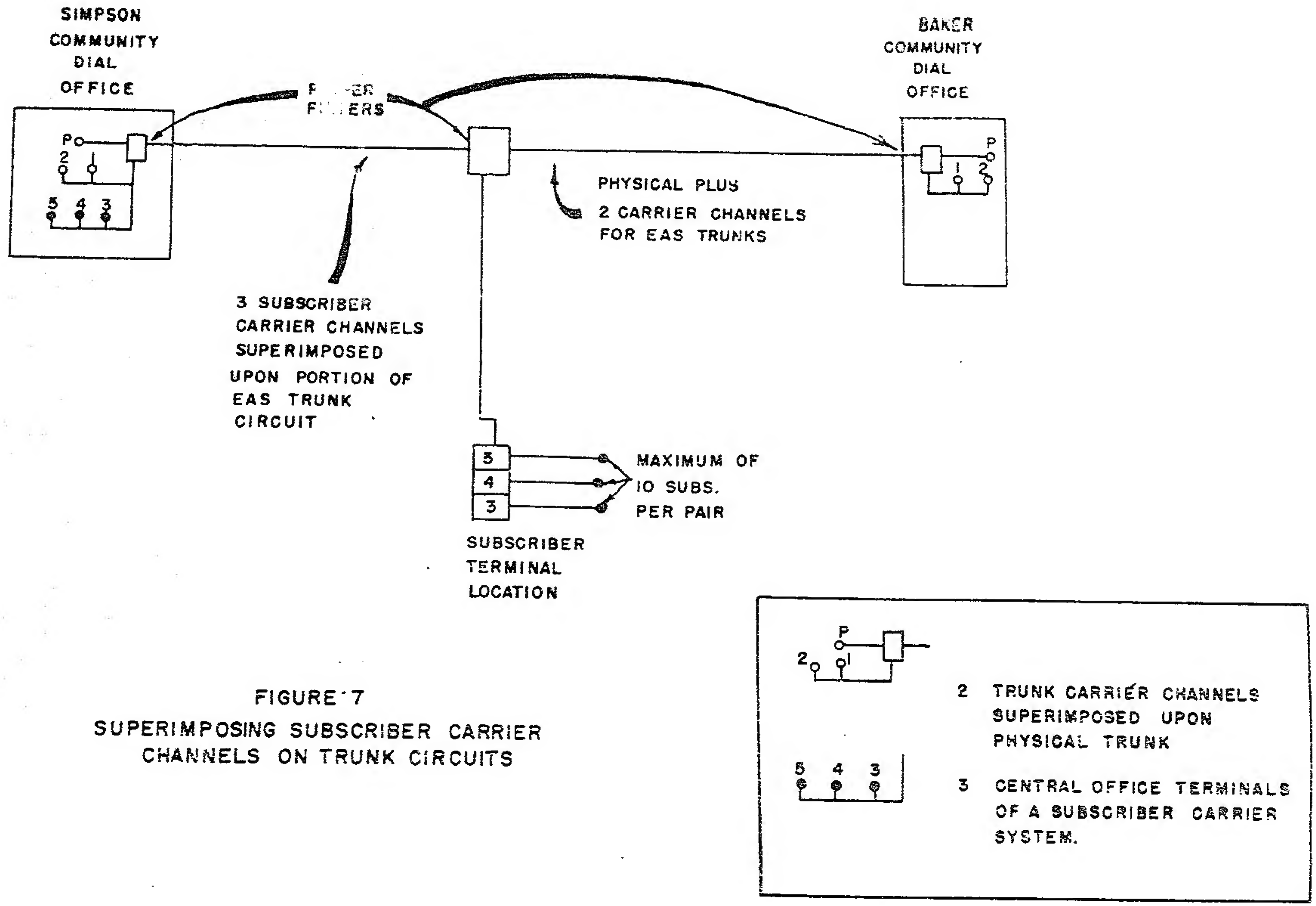



FIGURE 7
SUPERIMPOSING SUBSCRIBER CARRIER CHANNELS ON TRUNK CIRCUITS

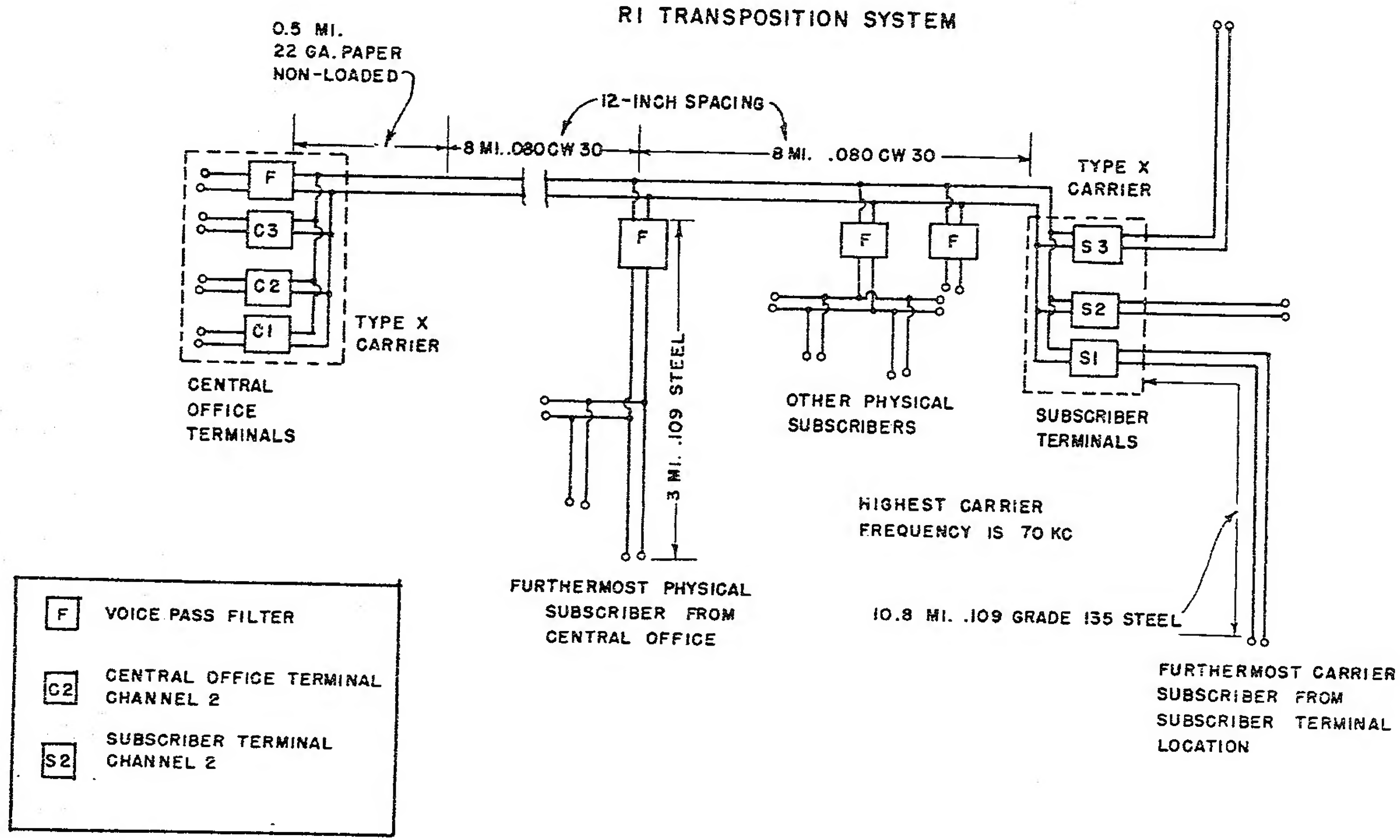



FIGURE 8 TYPE OF LAYOUT NEEDED TO DETERMINE IF BOTH VOICE AND CARRIER FREQUENCY TRANSMISSION ARE SATISFACTORY

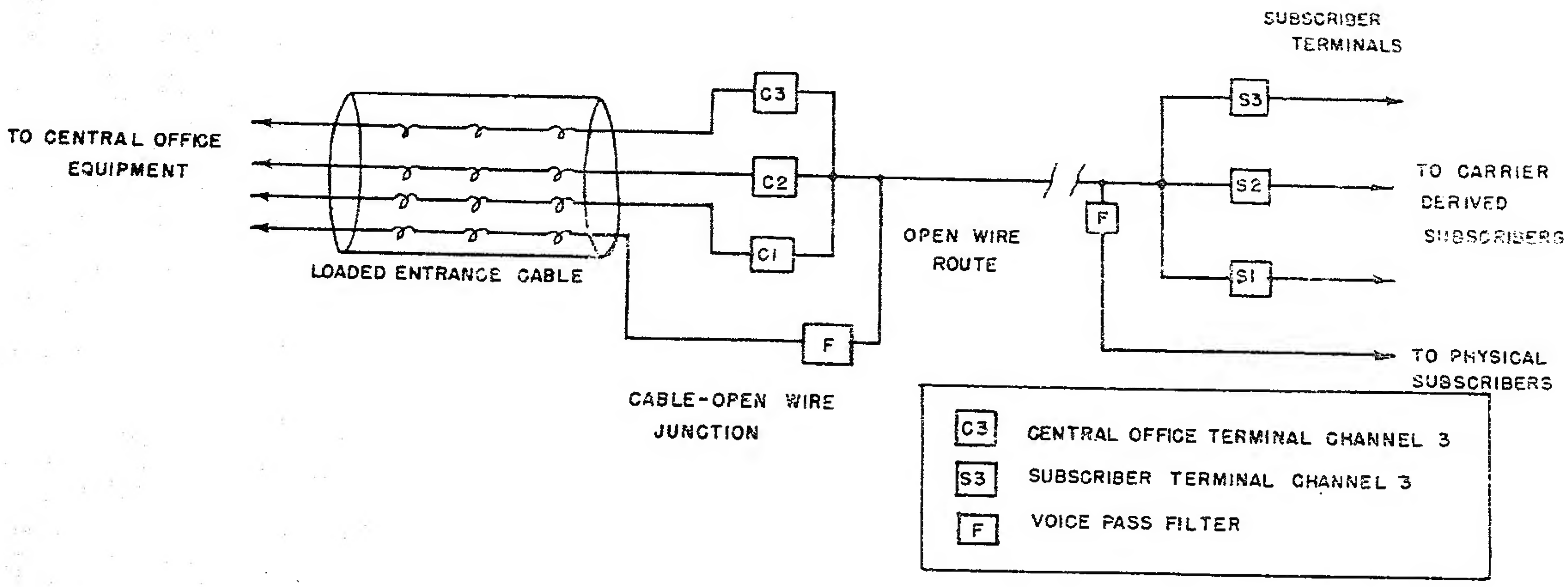



FIGURE 9. POLE MOUNTING OF CENTRAL OFFICE TERMINALS OF SUBSCRIBER CARRIER EQUIPMENT WHEN ALL PAIRS OF ENTRANCE CABLE ARE VOICE FREQUENCY LOADED, WHERE THE CARRIER FREQUENCY ATTENUATION DUE TO THE ENTRANCE CABLE WOULD BE EXCESSIVE OR WHERE THERE IS KNOWN EXCESSIVE CARRIER CROSSTALK DUE TO THE ENTRANCE CABLE.

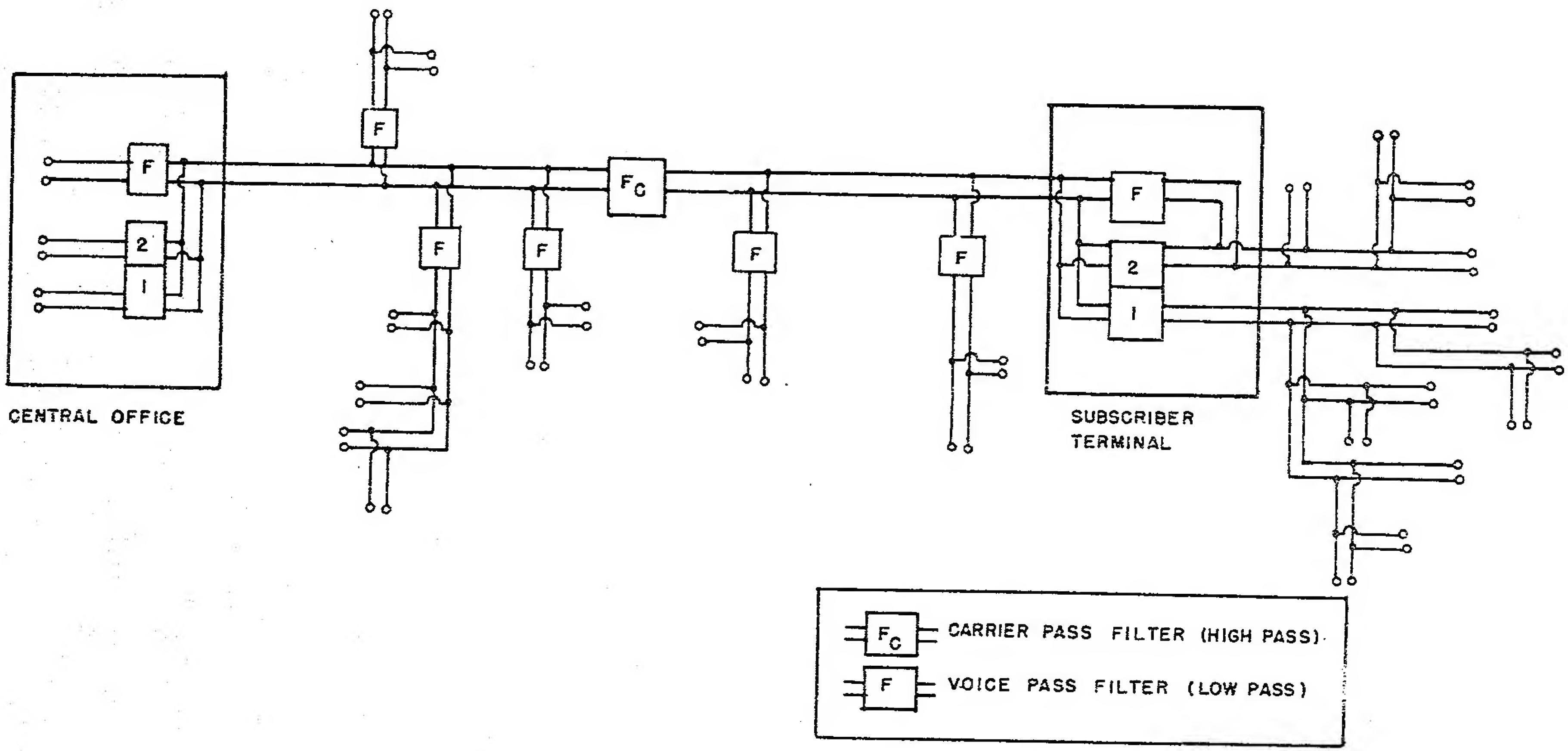



FIGURE 10 USE OF CARRIER AND VOICE PASS FILTERS WITH ONLY ONE WIRE PAIR BETWEEN CARRIER TERMINALS FOR CARRIER TRANSMISSION AND TWO VOICE FREQUENCY CIRCUITS.

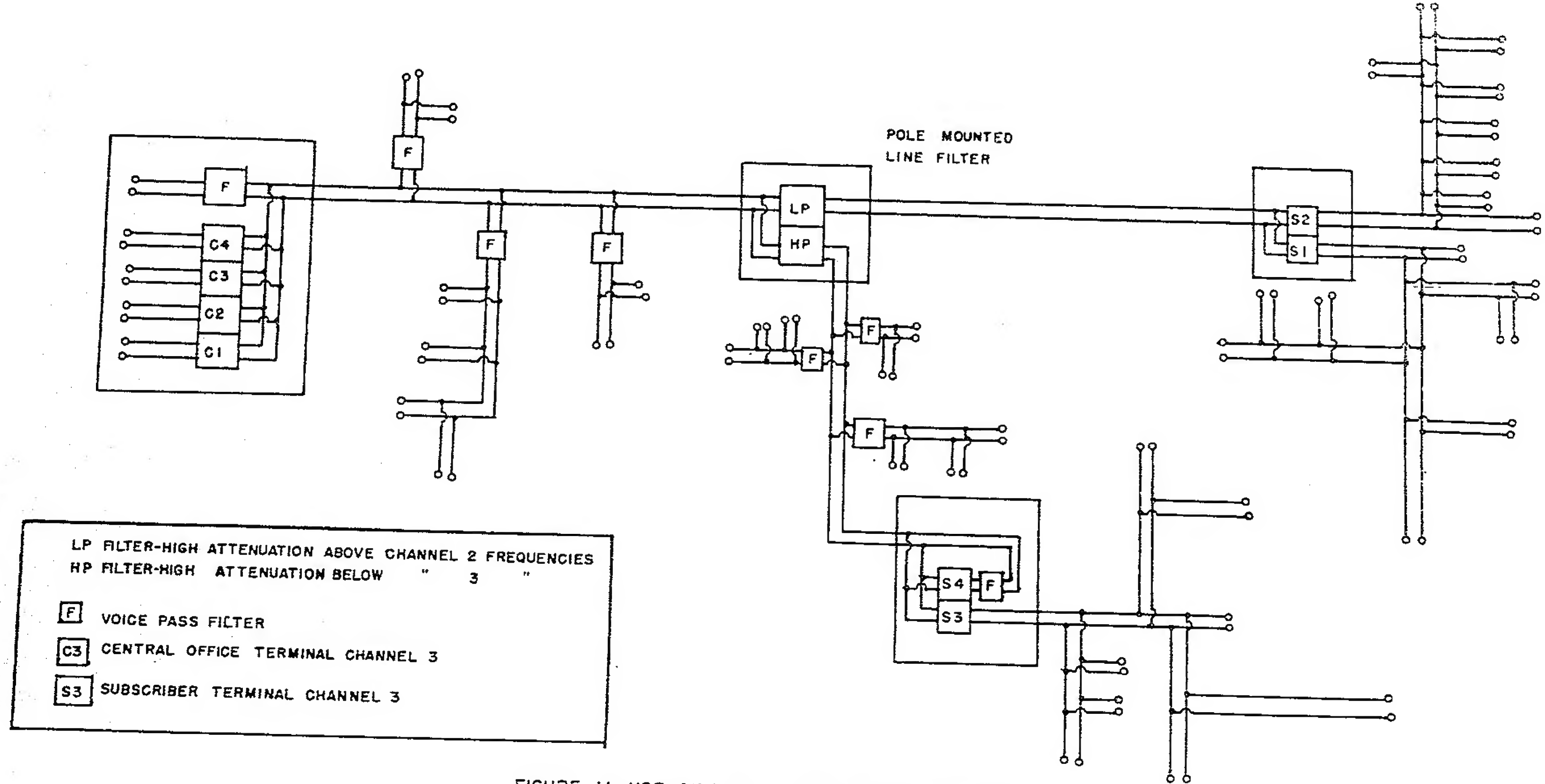
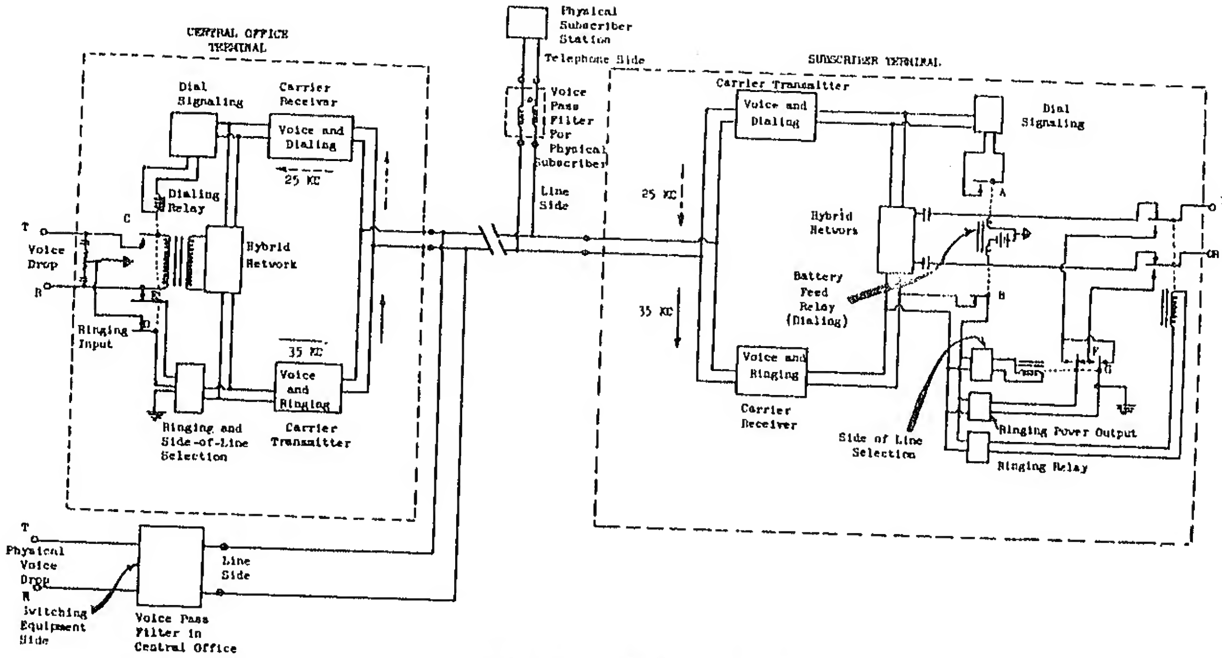



FIGURE 11 USE OF LINE FILTER IN APPLICATIONS WHERE CARRIER CHANNELS ARE CONNECTED TO LINE AT INTERMEDIATE LOCATION




DIALING, TALKING AND RINGING CONDITIONS OF RELAYS

1. <u>On-Hook Condition:</u>
   All Relays Shown in On-Hook Condition on Drawing.

2. <u>With Off-Hook Condition At Subscriber Terminal:</u>
   Ringing Relay Released as Shown on Drawing.
   Battery Feed Relay Operates at Subscriber Terminal.
   "A" Contact Sends Signal to Central Office Carrier Terminal.
   "B" Contact Disconnects Ringing Circuitry at Subscriber Terminal.
   Dialing Relay Releases at Central Office Terminal.
   "C" Contact Closes D.C. Path Into Central Office Equipment.
   "D" and "E" Contacts Disconnect Ringing Circuitry at Central Office Terminal.

3. <u>Dialing:</u>
   Ringing Relay Released As Shown On Drawing.
   Battery Feed Relay Operates and Releases And Dialing Relay Releases And Operates, Respectively, in Accordance With Dial Pulses.

4. <u>Talking:</u>
   Ringing Relay Released As Shown on Drawing.
   Battery Feed Relay Operated.
   Dialing Relay Released.

5. <u>Ringing - Tip to Ground:</u>
   Dialing Relay Operated as Shown on Drawing.
   Battery Feed Relay Released.
   C.O. Ringing Power Applied to Central Office Terminal Ringing Circuitry Thru "D" Contact of Dialing Relay.
   Ground Applied by C.O. Equipment to Ring Side of Line and Thru "E" Contact of Dialing Relay to Ringing Circuitry.
   Side-of-Line Selection Relay at Subscriber Terminal Operates to Place Ground on "F" Contacts.
   Ringing Relay Operates For Each Application of Ringing Voltage at the Central Office Terminal and Applies the Ringing Output Power (Regenerated at the Subscriber Terminal) Between the Tip Side of the Line and Ground.

6. <u>Ringing - Ring to Ground:</u>
   Dialing Relay Operated as Shown on Drawing.
   Battery Feed Relay Released.
   C. O. Ringing Power Applied to Central Office Terminal Ringing Circuitry Thru "D" Contact of Dialing Relay.
   Ground Applied by C.O. Equipment to Tip Side of Line. Ground is Not Applied Through "E" Contact to Ringing Circuitry.
   Side-of-Line Selection Relay at Subscriber Terminal Remains in Released Condition as Shown on Diagram To Place Ground on "G" Contact.
   Ringing Relay Operates for Each Application of Ringing Voltage At the Central Office Terminal and Applies the Ringing Output Power (Regenerated at the Subscriber Terminal) Between the Ring Side of the Line and Ground.

FIGURE 12 BLOCK DIAGRAM OF A SUBSCRIBER CARRIER CHANNEL SUPERIMPOSED ON A PHYSICAL CIRCUIT TO INDICATE SIGNALING FUNCTIONS

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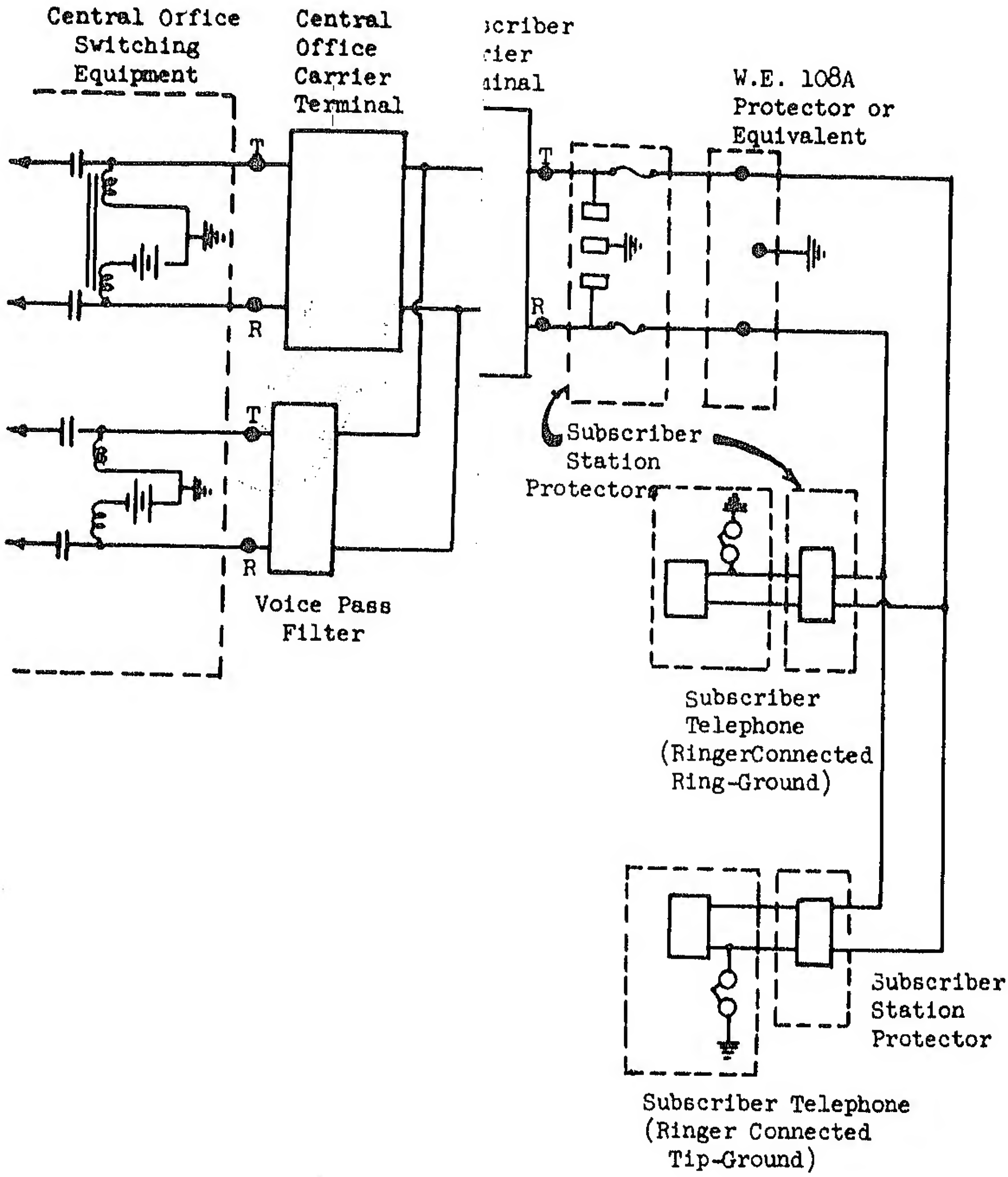
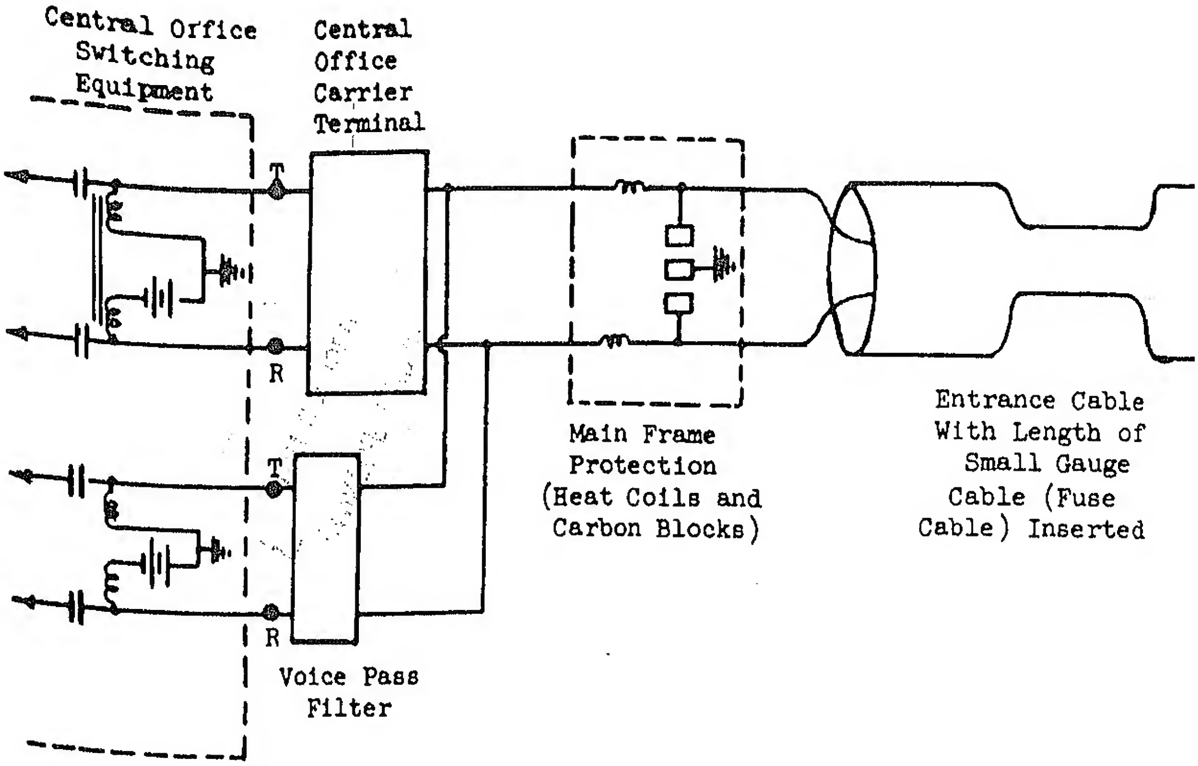
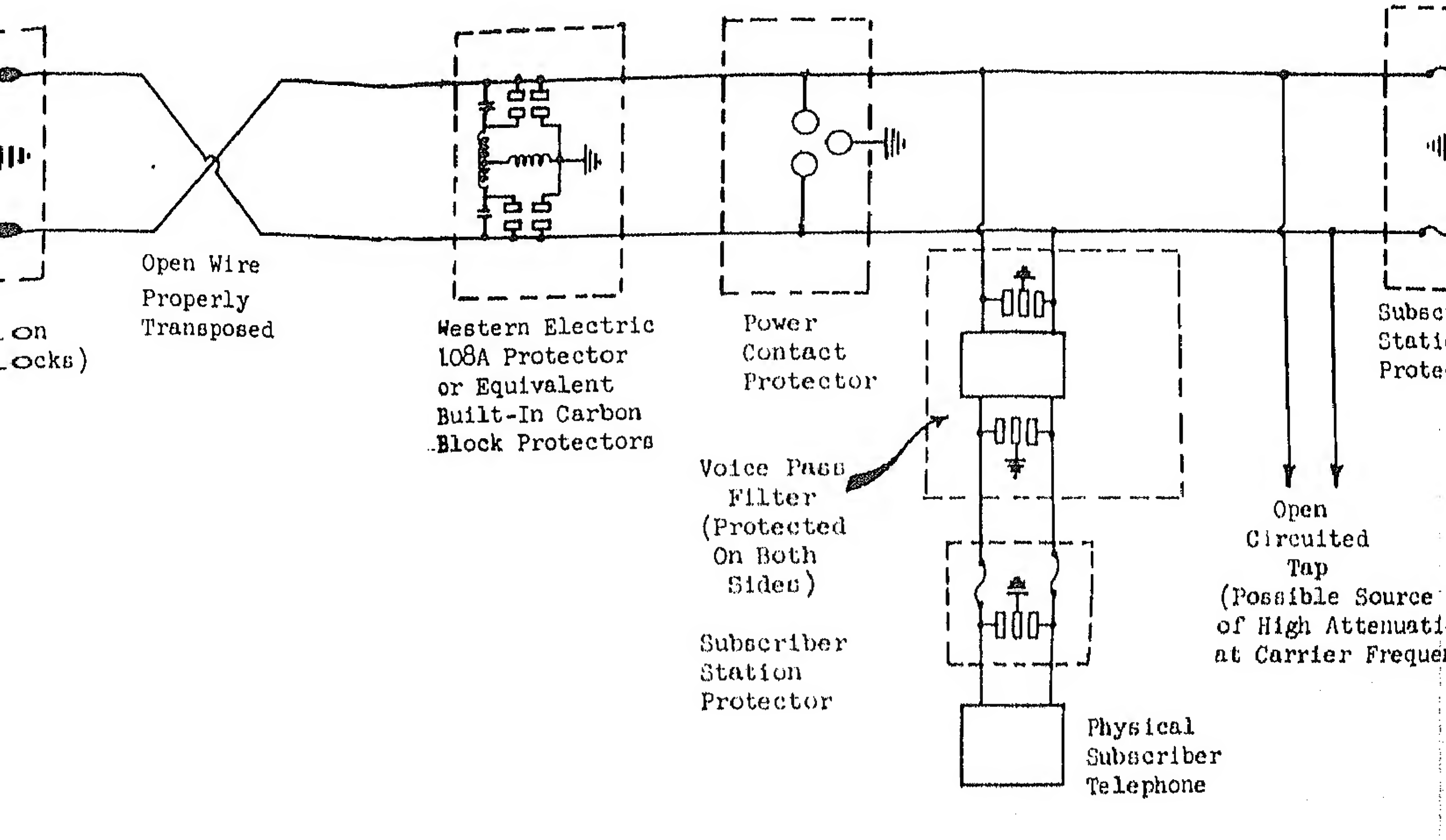

Central Office
Switching
Equipment
Central
Office
Carrier
Terminal
scriber
rier
inal
W.E. 108A
Protector or
Equivalent
T
R
T
R
T
R
Voice Pass
Filter
Subscriber
Station
Protectors
Subscriber
Telephone
(RingerConnected
Ring-Ground)
Subscriber
Station
Protector
Subscriber Telephone
(Ringer Connected
Tip-Ground)


Central Office
Switching
Equipment
Central
Office
Carrier
Terminal
T
R
T
R
Voice Pass
Filter
Main Frame
Protection
(Heat Coils and
Carbon Blocks)
Entrance Cable
With Length of
Small Gauge
Cable (Fuse
Cable) Inserted




PICAL WIRE FACILITIES AND TYPES OF PROTECTION UTILIZED WHEN A
ER CARRIER CHANNEL IS SUPERIMPOSED UPON A PHYSICAL CIRCUIT

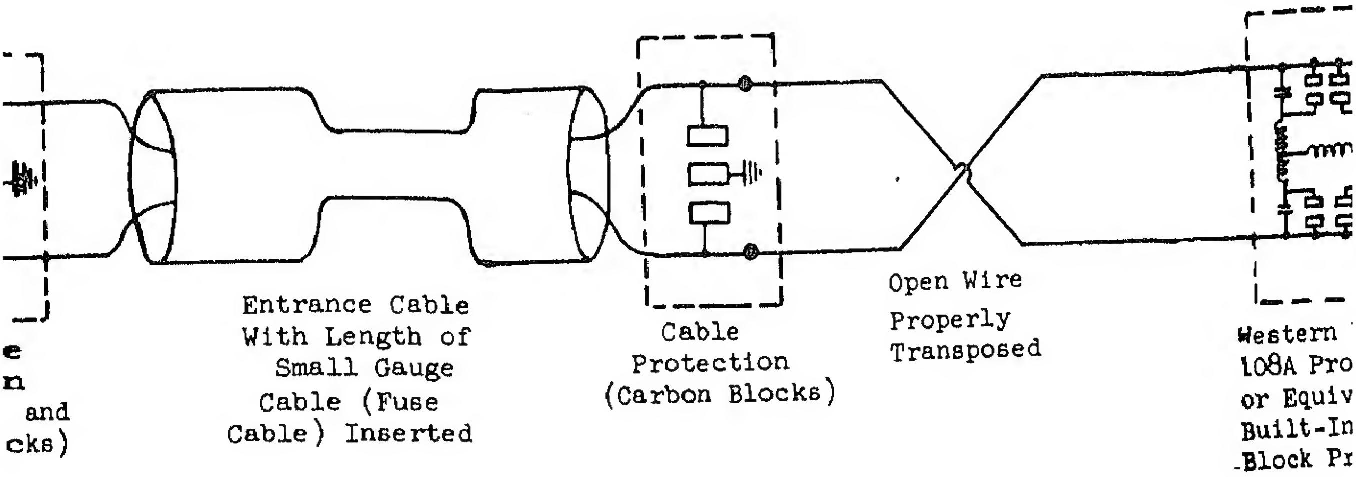
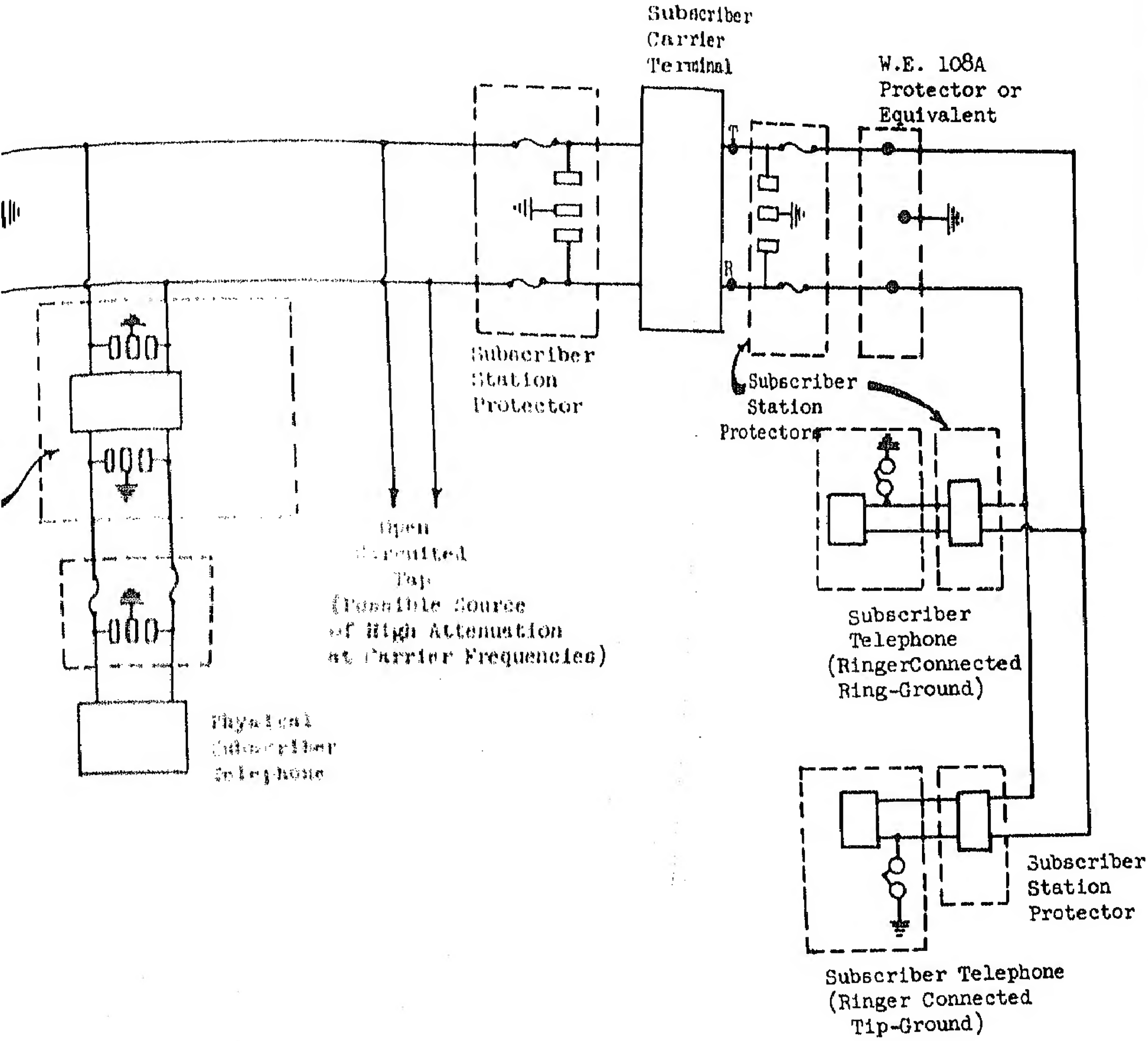



FIGURE 13 TYPICAL WIRE FACILITIES AND TYPES OF PRO
SUBSCRIBER CARRIER CHANNEL IS SUPERIMPOSED UPO


Subscriber
Carrier
Terminal
W.E. 108A
Protector or
Equivalent
T
R
Subscriber
Station
Protector
Subscriber
Station
Protectors
Open
Circuited
Tap
(Possible Source
of High Attenuation
at Carrier Frequencies)
Subscriber
Telephone
(RingerConnected
Ring-Ground)
Physical
Subscriber
Telephone
Subscriber
Station
Protector
Subscriber Telephone
(Ringer Connected
Tip-Ground)